THURSDAY, SEPTEMBER 19, 1895.

THE BRITISH ASSOCIATION.

WEDNESDAY.

THE British Association meeting at Ipswich has now practically come to an end. The stream of strangers which set towards the town a week ago shows signs of retiring, and, in the course of a day or two, the ancient and interesting county town of Suffolk will have returned to its normal condition. The meeting has been a very pleasant one for all, and the delightful weather of the past week has naturally attracted a large attendance at each of the many enjoyable excursions to places of interest in the surrounding country. The Association has often met in places far richer in educational and scientific institutions than Ipswich, but it has rarely met in a centre within easy reach of picturesque scenery offering more facilities for geological observation, or possessing a greater abundance of objects of interest to students of antiquities. This, combined with the fact that papers of extreme value have been communicated to each of the Sections, will make the meeting memorable to all who have attended it. As we shall follow our usual custom of giving reports of the work done in the Sections, it is unnecessary here to do more than refer to one or two of the papers and discussions which have excited general interest.

The subject of scientific research was brought up in Section A by Sir Douglas Galton's description of the Reichanstalt, Charlottenburg. After giving a full account of the construction, endowment, and management of that institution, which has for its object "the development of pure scientific research and the promotion of new applications of science for industrial purposes," it was pointed out that, in this country, there is no Government department which approximates to it. Recognising our deficiency in this respect, the suggestion was made that a committee of inquiry take the matter up, with the idea of formulating some definite proposal for the establishment of a central institution where standardising and research could be carried on without interruption. If the ideas with reference to such an institution should take tangible shape, as we sincerely hope they will, the Ipswich meeting will be remarkable in the annals of the Association as one from which a new departure in national enterprise began.

The joint meeting of Sections A and B, on Friday, was marked by two important communications on argon and helium. By methods which command the admiration of every one who can appreciate scientific inquiry, Lord Rayleigh showed how he had measured the refraction and viscosity of the two new gases. The refractive index of argon turns out to be 0·961, while that of helium appears to be as low as 0·146; both being compared with dry air. With the viscosity of dry air as the standard of comparison, those of argon and helium were respectively 1·21 and 0·96. Another interesting matter referred to by Lord Rayleigh in the course of his communication was the nature of the gas from the mineral spring at Bath. Some months ago, before the discovery of terrestrial helium, Lord Rayleigh and Prof. Ramsay examined samples of that gas for argon, but without finding the new element. The results were such, however, that an examination of the gas for helium was lately undertaken, and Lord Rayleigh was able to say that he had proved spectroscopically that helium really exists in the Bath gas. The question as to the nature of helium itself was elucidated by Prof. Runge in his contribution to the discussion of "the evidence to be gathered as to the simple or compound character of a gas from the constitution of its spectrum." It may be remembered that a short time ago, Prof. Runge contributed to these columns an article on the analysis of spectra by investigation of the periodic distribution of wave-lengths. He took the spectrum of lithium as a typical example of a spectrum which could be resolved into two spectra, the lines in each of which were connected by a simple formula. Taking his own observations of the spectrum of helium, Prof. Runge showed that helium is not an element but consists of two, and not more than two, elements. The conclusion is arrived at because the helium spectrum can be resolved into two sets of lines each apparently distinct from the other.

Of all the Sections, those of Geography and Anthropology have attracted the largest attendance, owing doubtless to the fact that the subjects dealt with could be easily followed, and are of general interest. But, besides the more or less popular papers of a resurrectionary character, a large number of distinctly new subjects have been brought up and discussed. The difficulty has been to find time for the long lists published in each day's *Journal*, and this difficulty is increased by the apparent inability of some of the readers of papers to express their conclusions in concise language. On account of the lack of this quality, the time for discussions has in several cases been very limited, and thus the first aim of a meeting of scientific men has been defeated.

At a meeting of the General Council, the question of Antarctic exploration was brought forward by the Royal Geographical Society, with a view to co-operation, and to the undertaking being unanimously advocated by the scientific societies of Great Britain and Ireland. The Council expressed their sympathy with, and approval of, the effort which was being made to organise an expedition for the exploration of the Antarctic Sea, but did not consider that any further action could usefully be taken by them at present.

As to the official affairs of the Association, Prof. Schäfer has been elected General Secretary in the place of Sir Douglas Galton, the present President. Sir W. H. Flower has been elected to represent the Association at the International Congress of Zoology at Leyden.

The retiring members of the Council were Prof. Lankester, Prof. Liveing, Mr. Preece, Prof. Reinold, and Prof. J. J. Thomson; and the new members elected to serve on the Council were Prof. Vernon Harcourt, Prof. Poulton, Prof. W. N. Shaw, Mr. Thiselton-Dyer, and Prof. J. M. Thomson.

The General Committee resolved on Monday that Sir Joseph Lister be appointed President-elect for the meeting at Liverpool next year. Prof. Herdman, Mr. J. C. Thompson, and Mr. W. E. Willink were appointed local secretaries for that meeting, and Mr. R. Bushell local treasurer. The Vice-Presidents-elect nominated for the meeting were the Lord Mayor of Liverpool (1896), the Earl of Sefton, the Lord-Lieutenant of the County of Lancaster, the Earl of Derby, Sir W. B. Forwood, Sir H. E. Roscoe, Mr. W. Rathbone, and Mr. W. Crookes. An invitation to hold the meeting in 1897 in Toronto, supported by cordial letters from British Columbia, from the University of Toronto, and Colleges of Manitoba, was accepted.

The following is a synopsis of the grants of money appropriated to scientific purposes by the General Committee this morning. The names of the members entitled to call on the General Treasurer for the respective grants are prefixed:—

	£	s.	d.
Mathematics and Physics.			
*Prof. Carey Foster—Electrical Standards (and unexpended balance in hand)	£5	0	0
*Mr. G. J. Symons—Photographs of Meteorological Phenomena...	15	0	0
*Lord Rayleigh—Mathematical Tables (unexpended balance)			
*Mr. G. J. Symons—Seismological Observations...	80	0	0
Dr. E. Atkinson—Abstracts of Physical Papers ...	100	0	0
*Rev. R. Harley—Calculation of Certain Integrals (renewed)	15	0	0
*Prof. S. P. Thompson—Uniformity of Size of Pages of Transactions, &c. (renewed)... ...	5	0	0
*Sir G. G. Stokes—Solar Radiation	30	0	0
Chemistry.			
*Sir H. E. Roscoe—Wave-length Tables of the Spectra of the Elements	10	0	0
*Dr. T. E. Thorpe—Action of Light upon Dyed Colours	5	0	0
*Prof. J. E. Reynolds—Electrolytic Quantitative Analysis (renewed)	10	0	0
Prof. R. Warrington—The Carbohydrates of Barley Straw	50	0	0
Prof. R. Meldola—Report of the Discussion on the Relation of Agriculture to Science ...	5	0	0
Geology.			
*Prof. E. Hull—Erratic Blocks	10	0	0
*Prof. T. Wiltshire—Palæozoic Phyllopoda ...	5	0	0
*Mr. J. Horne—Shell-bearing Deposits at Clava, &c.	10	0	0
*Dr. R. H. Traquair—Eurypterids of the Pentland Hills	5	0	0
*Prof. T. G. Bonney—Investigation of a Coral Reef by Boring and Sounding (renewed) ...	10	0	0
*Prof. A. H. Green—Examination of the Locality where the Cetiosaurus in the Oxford Museum was found (£20 renewed)	25	0	0
Sir John Evans—Palæolithic Deposits at Hoxur...	25	0	0
Sir W. H. Flower—Fauna of Singapore Caves ...	40	0	0
T. F. Jamieson—Age and Relation of Rocks near Moreseat, Aberdeen	10	0	0
Zoology.			
*Dr. P. L. Sclater—Table at the Zoological Station, Naples	100	0	0
*Mr. G. C. Bourne—Table at the Biological Laboratory, Plymouth (£5 renewed)	15	0	0
*Prof. W. A. Herdman—Zoology, Botany, and Geology of the Irish Sea (partly renewed) ...	50	0	0
*Dr. P. L. Sclater—Zoology of the Sandwich Islands	100	0	0
Dr. P. L. Sclater—African Lake Fauna	100	0	0
Prof. W. A. Herdman—Oysters under normal and abnormal environment	40	0	0
Geography.			
*Mr. E. G. Ravenstein—Climatology of Tropical Africa	10	0	0
Mechanical Science.			
*Prof. A. B. W. Kennedy—Calibration and comparison of measuring instruments (£25 renewed)	30	0	0
Mr. W. H. Preece—Introduction of the B.A. Small Screw Gauge	10	0	0
Anthropology.			
*Prof. E. B. Tylor—North-Western Tribes of Canada (£76 15s. renewed)	100	0	0
*Dr. R. Munro—Lake Village at Glastonbury (£5 renewed)	30	0	0
*Sir J. Evans—Exploration of a Kitchen-midden at Hastings (unexpended balance)			
*Mr. E. W. Brabrook—Ethnographical Survey (£20 renewed)	40	0	0
*Sir Douglas Galton—Mental and Physical Condition of Children	10	0	0
Physiology.			
*Prof. J. G. McKendrick—Physiological Applications of the Phonograph	25	0	0
Corresponding Societies.			
*Prof. R. Meldola—For preparing Report ...	30	0	0
	£1160	0	0

* Reappointed.

PRESIDENTS' ADDRESSES (*continued*).

SECTION C.

GEOLOGY.

Underground in Suffolk and its Borders.

OPENING ADDRESS BY W. WHITAKER, B.A., F.R.S., F.G.S.

WHEN the British Association revisits a town it is not unusual for the Sectional Presidents to refer to the addresses of their local predecessors, and to allude to the advance of their science since the former meeting. I have at all events tried to follow this course, with the sad result of having to chronicle a falling back rather than an advance in our methods of procedure; for at the meeting of 1851 all the Sectional Presidents had the wisdom not to give an address, and of all the inventions of later years I look upon the presidential address as perhaps the worst.

Had I the courage of my opinion I should not now trouble you; but an official life of over thirty-eight years has led me to do what I am told to do, and to suppress my own ideas of what is right. After all it is the fault of the Sections themselves that they should suffer the evil of addresses. They could disestablish the institution without difficulty.

On these occasions it is not usual to allude to the personal losses our science has had in the past year; but there are times when the lack of a familiar presence can hardly be passed over, and since we last met we have lost one of our most constant friends, who had served us long and well, and had been our Secretary for a far longer time than any other holder of that office. When we were at Oxford last summer none of us could have thought that it was our last meeting with William Topley.

I do not now mean to say anything on the origin or on the classification of the various divisions of the Crag and of the Drift that occur so plentifully around us, and form the staple interest of East Anglian geology. These subjects, which are the more interesting from being controversial, I leave to my brother-hammerers, and without claiming the credit of magnanimity in so doing, having said what I had to say on them in sundry Geological Survey Memoirs. The object of this address is to carry you below the surface, and to point out how much our knowledge of the geology of the county in which we meet has been advanced by workers in another field, by engineers and others in their search for water. As far as possible allusion will be made only to work in Suffolk; but we must occasionally invade the neighbouring counties.

This kind of evidence has chiefly accumulated since the meeting of the Association at Ipswich, in 1851; for of the 476 Suffolk wells of which an account, with some geologic information, has been published, only sixty-eight were noticed before that year, all but two of these being in a single paper. The notes on all these wells are now to be found in twelve Geological Survey Memoirs that refer to the county. Number alone, however, is not the only point, and many of the later records are marked by a precision and a detail rarely approached in the older ones. It should be stated that in the above and in the following numbers strict accuracy is not professed, nor is it material. A slight error in the number of the wells, one way or the other, would make practically no difference to the general conclusions.

Now let us see how these records affect our knowledge of the various geologic formations, beginning with the newest and working downward.

The Drift.

Under this head, as a matter of convenience for the present purpose, we will include everything above the Chillesford Clay. There is no need for refinement of classification, and the thin beds that come in between that Clay and the Drift in some parts do not affect the evidence we have to deal with.

As a matter of fact it is only from wells that we can tell the thickness of the Drift over most of the great plateau that this formation chiefly forms; open sections through a great thickness of Drift, to its base, are rare, except on the coast.

There is often some doubt in classifying the beds, the division between Drift and Crag being sometimes hard to make in sections of wells and borings; but from an examination of the records of these Suffolk sections that pass through any part of the Drift Series (as defined above) we find that no less than 173 show a thickness of 50 feet and upward, whilst of these 34 prove no less than 100 feet of Drift, many reaching to much more. Of the two that are said to show a thickness of over 200 feet and the one other said to be more than 300 feet deep in Drift, we

can hardly feel certain; but such amounts have been recorded with certainty as occurring in the neighbouring county of Essex.

These great thicknesses (chiefly consisting of Boulder Clay) show the importance of the Drift, and the impossibility of mapping the formations beneath with any approach to accuracy, on the supposition that the Drift is stripped off, as is the case in the ordinary geologic map. The records also show the varying thickness of the Drift, and how difficult it often is therefore to estimate the thickness at a given spot. Sometimes the sections seem to point to the existence of channels filled with Drift, such as are found also in Essex and in Norfolk; and it may be noted that in the northern inland part of the former county, one of these channels has been traced, though of course not continuously, for some eleven miles along the valley of the Cam, and at one place to the depth of 340 feet (or nearly 140 below sea-level), the bottom of the Drift moreover not having been reached even then. A channel of this sort seems to occur close to us, in the midst of the town of Ipswich, where, by St. Peter's, one boring has pierced 70 feet of Drift, and another 127, in ground but little above the sea-level.

As the Drift sands and gravels, that in many places occur below the Boulder Clay, often yield a fair amount of water, the proof of their occurrence and of the thickness of the overlying clay is of some practical good.

The Crag.

On this geologic division we have a less amount of information, as would be expected from the fact that it is not nearly so widespread as the Drift, and this information is confined to the Upper, or Red, Crag, the Lower, or Coralline, Crag occurring only over a very small area, and no evidence of its underground extension being given by wells.

What we learn of the Red Crag, however, is of interest, several wells having proved that it is far thicker underground than would have been supposed from what is seen where its base crops out. One characteristic, indeed, of this sandy deposit, in the many parts where it can be seen from top to bottom, is its thinness, as in such places it rarely reaches a thickness of 40 feet. But, on the other hand, wells at Hoxne seem to prove more than 60 feet of Crag, whilst at Saxmundham the formation is 100 feet thick, and at Leiston and Southwold over 140. Further north, just within the border of Suffolk, there is, at Beccles, a thickness of 80 feet of sand, or, with the overlying Chillesford Clay, a total of 95. Our underground information has, then, trebled the known thickness of the Upper Crag of Suffolk.

It has also shown that at some depth underground the colour-name is a misnomer, the shelly sands being light-coloured and not red. This is the case too with some other deposits, which owe their reddish-brown colour at the surface to peroxide of iron. Presumably the iron-salt is in a lower state of oxidation until it comes within reach of surface-actions. This seems to point to the risk of taking colour as the mark of a geologic formation.

Eocene Tertiaries.

Below the Crag there is a great gap in the geologic series, and we come to some of the lower of the Tertiary formations, about which little had been published, as regards Suffolk, before the work of the Geological Survey in the county. It seems as if the special interest in the more local Crag had led observers to neglect these beds, which had been amply noticed in other parts.

We have records of more than forty wells in Suffolk that are partly in these deposits, and of these thirty-six reach down to the Chalk, twenty giving good sections from the London Clay to the Chalk. The thickness of the Lower London Tertiaries (between those formations) thus proved varies from 30 to 79½ feet, the higher figure being much greater than anything shown at the outcrop. The greatest recorded thickness is at Leiston, where, moreover, the top 26 feet of the 79½ may belong to the uppermost and most local of the three divisions of the series, the Oldhaven Beds, of very rare occurrence in the county. The next greatest thickness is at Southwold, where the whole has been classed as Reading Beds (the persistent division), though here and elsewhere it is possible that the underlying Thanet Beds are thinly represented. It is noteworthy that at both these places, where the Lower London Tertiaries are thick, they are also at a great depth, beginning at 252½ and 218 feet respectively, which looks as if, like the Crag, they thickened in their underground course away from the outcrop.

The important evidence given by these wells, however, is not as regards thickness; it is to show the underground extent of the older Tertiary beds, beneath the great sheet of Crag and Drift that prevents them from coming to the surface north-eastward from the neighbourhood of Woodbridge. It is clear that over this large tract we can know nothing of the beds beneath the Crag otherwise than from wells and borings; and, until these were made, our older geologic maps cut off the older Tertiary beds far south of the parts to which we now know that they reach, though hidden from our sight. No one, for instance, would have imagined many years ago that at Southwold the Chalk would not be touched till a boring had reached the depth of 323 feet, or some 280 below sea-level, nor that at Leiston those figures would have been about 297 and 240.

It is from calculations based on the levels of the junction of the Chalk and the Tertiary beds in many wells that the line engraved on the Geological Survey map as the probable boundary of the latter beds under the Crag and Drift has been drawn. From what has gone before, however, as to the great irregularity in the thickness of the Drift, it is clear that this line must be taken only as approximate, and open to correction as further evidence is got; albeit the junction of the Chalk and the Tertiary beds is found to be here, as elsewhere, fairly even, along an inclined plane that sinks towards the coast.

Cretaceous Beds.

Though the *Chalk* is reached by very many wells, yet we get less information about it, by reason of its great thickness. Moreover, the great amount of overlying beds in many cases is a bar to deep exploration.

Of our Suffolk wells there are forty which go through 100 feet or more of Chalk. Of these twenty go through 200 feet or more, half of these to 300 or more, and again half of the ten to 400 or more, a very exact piece of geometric progression, or more strictly, retrogression. Although two wells pass through the great thickness of more than 800 feet of Chalk, yet neither of them gives us the full thickness of the formation; for the 816 feet at Landguard Fort do not reach to the base, whilst the 843 (or 817) feet at Combs, near Stowmarket, do not begin at the top.

As in no case yet recorded has the Chalk been pierced from top to bottom in Suffolk (a defect that will be supplied during this meeting by the description of the Stutton boring), that is to say, no boring has gone from the overlying older Tertiary beds to the underlying Gault, we must now, therefore, cross the border of the county to get full information as to the thickness of the Chalk; and we have not far to go, for the well-known Harwich boring passes through the whole of the Chalk, proving a thickness of 890 feet. It is almost certain, indeed, that this should be given as a few feet more, for the 22 feet next beneath, which have been described as Gault mixed with Greensand, is probably in part the green clayey glauconitic base of the Chalk Marl. We may fairly add to this number 5 feet (as also in the case of the Combs boring), and may say that, in round numbers, the Chalk reaches a thickness of about 900 feet in the south-eastern part of Suffolk. Toward the northern border of the county it is probably more, as the deep boring at Norwich passes through nearly 1160 feet of Chalk, and that without beginning at the top of the formation.

Of our recorded Suffolk wells only three reach the base of the Chalk, at Mildenhall, Culford and Combs; consequently we have little knowledge of the divisions of the Chalk. These divisions, indeed, are of comparatively late invention, having been evolved since the publication of many of the deep sections that have been referred to.

If the Upper Chalk at Harwich goes as far down as the flints, then we must allow it to be 690 feet thick, leaving little more than 200 for the Middle and Lower Chalk together. At Landguard Fort, from the same point of view, th Upper Chalk would certainly be 500 feet thick, and one cannot y how much more.

At Combs, on the other hand, flints have been recorded as present only in the top 27 feet of the Chalk; but whilst this may have been owing in part to the boring having passed between fairly scattered nodules, and in part, perhaps, to insufficient care in observation, at Harwich it is possible that some flints may have been carried down in the process of boring.

What evidence we have tends to show, however, that the Upper Chalk forms a good deal more than half, and perhaps about two thirds, of the formation, the Middle and Lower Chalk

being rather thin. This agrees with what is found in other parts where the Chalk is thick, extra thickness being chiefly due to the highest division. The glauconitic marly bed at the base seems to be well developed and to be underlain by the Gault clay; so that we have no good evidence of the occurrence of Upper Greensand. This division may be thinly represented at Mildenhall, but it is difficult to classify some of the beds passed through in the old boring there.

As far as the *Gault* is concerned, little, of course, is known; but that little points to this formation being unusually thin, presumably only 73 feet from top to bottom at Culford, and probably not more than between 50 and 60 at and near Harwich. In the north-western part of the neighbouring county of Norfolk it is well known to be still less, the clay thinning out northward along the outcrop, until at last there is nothing but a few feet of Red Chalk between the carstone of the Lower Greensand and the Chalk. The Gault being of much greater thickness around and under other parts of the London Basin, this thinning in Norfolk and Suffolk is noteworthy. The absence of the more inconstant Upper Greensand is to be expected in most places, and calls for no remark; it may, however, be noted that geologists are coming to the conclusion that these two divisions are really parts of one formation, and one result of this geologic wedding is for the inconstancy of one partner to be greatly compensated by the constancy of the other.

The *Lower Greensand* has been found in one deep boring only, at Culford, in the western part of the county, where it is represented by 32½ feet of somewhat exceptional beds. This slight thickness prepares us for underground thinning, and in the far east of the county the formation is presumably absent, there being no trace of it at Harwich or at Stutton.

With the Cretaceous beds we pass from the regular orderly succession of geological formations; indeed, it may be said that when we reach the base of the Gault we pass out of the region of facts into the realm of speculation.

We have come, then, to perhaps the most interesting problem in the geology of the Eastern Counties, to the consideration of the question, What rocks underlie the Cretaceous beds at great depths? In dealing with this I must ask your patience for frequent excursions outside our special district, and sometimes indeed far away from it.

Beyond the outcrop of the lower beds of the Cretaceous Series in Cambridgeshire and Norfolk, we find of course a powerful development of the great Jurassic Series; but the only two recorded deep borings in and near Suffolk that have pierced through the Cretaceous base, at Culford on the north-west and at Harwich on the south-east, show not a trace of anything Jurassic: they pass suddenly from Cretaceous into far older rocks. And here a paper that is to be brought before you must be anticipated, to a slight extent, by adding that the trial-boring at Stutton shows just the same thing, the Gault resting directly on a much older rock, which cannot be classed as of Secondary age.

There is no need now to discuss the literature of the old rocks underground in south-eastern England, that has often been done. We may take the knowledge of what has been shown by the various deep borings as common property, and may use it freely, without troubling to state the source of each piece of information, and I will not therefore burden this address with references. I had indeed thought of supplementing a former account by noticing the later literature of the subject; but decided to spare you from the infliction, and myself from the trouble of inflicting; though it may be convenient to add, in the form of an Appendix, a list of the chief papers on the subject that have been published since the question was discussed at length in 1889, in an official memoir on the geology of London, and to supply some omissions in that work. Nor do I propose to make any special criticism of papers on the subject that have appeared of late years; this is hardly the occasion for controversy, which may well be put off to a more convenient season. Some general remarks, however, I shall have to make after putting the facts before you.

There are ten deep borings reaching to old rocks in the London Basin, of which accounts have been published. We find that in four of these (Meux's, Streatham, Richmond and Dover) Jurassic beds separate those rocks from the Cretaceous beds; so that there are six in which these last rest direct on old rocks (Ware, Cheshunt, Kentish Town, Crossness, Culford, and Harwich). Stutton of course makes a seventh. The Jurassic rocks occur only in the southern borings, either in London or still further southward, and in one case only (Dover) is there any considerable thickness of these: in the other three they are from 38½ to 87½ feet thick. As far as regards Suffolk and its borders we may therefore disregard them, except in the far west, near their outcrop, and we may pass on to consider the older rocks that have been found.

So far the occurrence, next beneath the Cretaceous or Jurassic beds, of Silurian, Devonian, and Carboniferous rocks has been proved, whilst in some cases we are still doubtful as to the age of the old rocks found. In five cases distinctive fossils have been found (Ware, Cheshunt, Meux's, Dover, and Harwich), but in five others they have not (Kentish Town, Crossness, Richmond, Streatham, and Culford), and it is in the latter group too that the character of the beds leaves their age in doubt. So far another must be added to these, as no fossil has yet been found in the old rocks at Stutton.

Of the above ten deep borings in the London Basin (using that term in the widest sense, as including the Chalk tract that everywhere surrounds the Tertiary beds) we owe nine to endeavours to get water from deep-seated rocks, and in addition to these nine we have several other deep borings, which though not carried through to the base of the Secondary rocks, yet give us much information concerning those beds (at Holkham, Norwich, Combs, Winkfield, London, Loughton, Chatham, and Dover). In one case only, that of Dover, has the work been done for the purpose of exploration, but now, after a few years' interval, a second trial has been made at Stutton.

Now both of these borings were started for a much more definite object than merely to prove the depth to older rocks, or the thickness of the Cretaceous and Jurassic Series. There is one particular division of those older rocks that has a distinct fascination for others than geologists. We, happily, are content to find anything and to increase our knowledge in any direction, but naturally those who are not geologists, as well as many who are, like to find something of immediate practical value. As already shown, we owe much knowledge of the underground extension of formations to explorations for water; it has now become the turn of geologists to help those who would like to find that much less general, though nearly as needful and certainly more valuable thing, *coal*.

The first place to suggest itself to those geologists who had worked at this question, as a good site for trial, was the neighbourhood of Dover, and for various good reasons. The trial has been made, and successfully, several hundred feet of Coal Measures having been found, without reaching their base, but with several beds of workable coal.

Beyond that neighbourhood, however, geologists are not in such accord, and generally speaking, fairly good reasons can be given both for and against the selection of many tracts for trial, except in and near London, where no geologists would recommend it, from the evidence in our hands.

Let us then shortly review the evidence that we have on the underground extension of the older rocks in south-eastern England, with a view of considering the question of the possibility of finding Coal Measures in any of the folds into which those rocks have probably, nay almost certainly, been thrown.

The area within which the borings that reach older rocks in the London Basin is enclosed is an irregular pentagon, from near Dover, on the south-east, to Richmond on the west, thence to Ware, thence to Culford on the north, thence to Harwich, and thence southward to Dover, the greatest distance between any borings being from Dover to Culford, about eighty-six miles. It is therefore over a large tract, extending of course beyond the boundaries sketched above, that we have good reason to infer that older rocks are within reasonable distance of the surface, nowhere probably as much as 1600 feet, and mostly a good deal less.

We must now consider some evidence outside the tract hitherto dealt with. Southward of the central and eastern parts of the London Basin we have evidence that the Lower Cretaceous beds thicken greatly, from what is seen over their broad outcrop between the North and South Downs. We know also, from the Dover and Chatham borings, that the Upper and Middle Jurassic beds come in to the south-east, whilst the Sub-Wealden Exploration, near Battle, proves that those divisions thicken greatly southward, the latter not having been bottomed at the depth of over 1900 feet, at that trial-boring.

Westward, however, near Burford in Oxfordshire, and some miles northward of the nearest part of the London Basin, Carboniferous rocks have been found at the depth of about 1180

feet, these being separated from the thick Jurassic beds (including therein the Liassic and Rhætic) by perhaps 420 of Trias. They consist of Coal Measures, which were pierced to the depth of about 230 feet.

In and near Northampton, north-eastward of the last site, and still further from the northern edge of the London Basin, the like occurs; but the beds found are older than the Coal Measures, and the Trias is thin, not reaching indeed to 90 feet in thickness, and being absent in one case. At one place, too, the Carboniferous beds have been pierced through, with a thickness of only 222 feet, when Old Red Sandstone was found, and in another place still older rock seems to have been found next beneath the Trias. The depth to the rocks older than the Trias, where they were reached, was 677, 738, and 790 feet, or respectively 395, 460, and 316 below sea-level. Some of these figures must be taken as somewhat approximate, though they are near enough to the truth for practical purposes.

A boring at Bletchley, to the south, reached granitic rocks at the depths of 378½ and 401 feet; but these rocks seem to be only boulders in a Jurassic clay: their occurrence, however, is suggestive of the presence of older rocks at the surface no great way off, in Middle Jurassic times.

Much further northward, at Scarle, south-west of Lincoln, the older rocks have been reached at the depth of about 1500 feet, all but 141 of which are Trias, and they begin with the Permian (which crops out some eighteen miles westward), the Carboniferous occurring after another 400 feet, and having been pierced to 130.

We have then evidence that over a large part of south-eastern England, reaching northward and westward of the London Basin, though the older rocks are hidden by a thick mantle of Jurassic, Cretaceous, and Tertiary beds, yet they seem to be rarely at a depth that would be called very great by the coal-miner. They are distinctly within workable depths wherever they have been reached.

There is no area of old rocks at the surface in our island, south of the Forth, in which Coal Measures are not a constituent formation. Truly, further north, in the great tract of Central and Northern Scotland there are no Carboniferous rocks; but we can hardly say that none ever occurred, at all events in the more southern parts. We know, though, that on the west and north Jurassic and Triassic beds rest on formations older than the Carboniferous.

It is not, however, to this more northern and distant tract that we should look for analogy to our underground plain of old rocks; rather should we look to more southern parts, to Wales and to central and northern England, where Coal Measures are of frequent occurrence. On the principle of reasoning from the known to the unknown, I cannot see why we should expect anything but a like occurrence of Coal Measures, in detached basins, in our vast underground tract of old rocks.

What, then, is the evident conclusion from what we know and from what we may reasonably infer? Surely that trials should be made to see if such hidden coal-basins can be found.

One trial has been made, and it has succeeded; the Dover boring has proved the presence of coal underground in Eastern Kent, along the line between the coal-fields of South Wales and of Bristol on the west, and those of Northern France and of Belgium on the east.

The long gap between the distant outcrops of the Coal Measures near Bristol and Calais has been lessened very slightly by the working of coal under the Triassic and Jurassic beds near the former place, but much more by our brethren across the narrow sea, the extent of the Coal Measures, beneath the Jurassic and Cretaceous beds, having not only been proved by the French and the Belgians along their borders, but the coal having been largely worked. At last, we too have still further decreased the gap, by the Dover boring, a work that I trust is to be followed by other work along the same line.

But is this the only line along which we are to search? Are we to conclude that the only coal-fields under our great tract of Cretaceous beds (where these are either at the surface or covered by Tertiary beds) are in Kent, Surrey, and other counties to the west? Have we no coal-fields but those of Bristol and of South Wales? The bounds of our midland and northern coal-fields have been extended by exploration beneath the New Red Series; are we to stop here and to assume that there can be no further underground extension of the Coal Measures south-eastward? This seems hardly a wise course, and is certainly a very unenterprising one. It seems to me rather that the right thing to be done is to try to find out the real state of things, by means of borings.

There are, of course, objectors in this as in other matters. Some may say that it is silly to try in Suffolk, and that Essex gives a better chance of success. Others, again, may prefer Norfolk. And yet others may argue that there is no chance of finding Coal Measures in any of those three counties. But I must confess my inability to understand this line of reasoning; the fact is that the data we have are few and far between, and that we want more. It is really of little use to bandy words, and I do not now mean to take up the matter in detail. We cannot get at the truth except by actual work; justification by faith will not hold in this case, still less justification by unfaith.

Let us hark back a little and call to mind what has happened in the past. I remember the time when certain geologists disbelieved in the possibility of the occurrence of Coal Measures anywhere in south-eastern England, it being argued that the formation thinned out before it could get so far eastward. Then this view was somewhat varied, and it was inferred, from certain observed facts, that even if Coal Measures did reach underground into these benighted parts, they would be without workable coal, and so practically useless.

Now for some years nothing occurred to upset the prophets of evil, that is to say, no fact came to light. There were not wanting inferences to the contrary, but it remained practically a matter of opinion. One day, however, the needful fact came, and the first boring made specially to test the question (at Dover) disproved both the above negative theories by finding Coal Measures with workable coal. Let us hope that a like result may happen in East Anglia, and that the pessimists may again be in the wrong.

We should not, however, fall into the opposite error, that of optimism. We must not expect an immediate success like that at Dover. We are here much further from any known coal-field. Advertisements of various wares sometimes tell us that "one trial will suffice," but it is not so in this case. We should not be content until many borings have been made, and we should not be despondent if, after sites have been selected to the best of our judgment, we begin with a set of borings that are unsuccessful in finding coal.

At the time of writing I cannot say that the Stutton boring is a success or a failure as far as coal is concerned, but I am quite ready to accept the latter without being discouraged. Whatever it is you may know during our meeting; it is certainly a success in the matter of reaching the old rocks at a depth of less than 1000 feet. We should remember that every boring is almost certain to give us some knowledge that may help in future work.

There is a further point, however, to be taken into account. A boring that may at first seem to be a failure, from striking beds older than the Coal Measures, may some day turn out otherwise. The coal-field along the borders of France and Belgium is sometimes affected by powerful and peculiar disturbances, by faults of comparatively gentle inclination (far removed from the usual more or less vertical displacements) which have thrown Coal Measures beneath older beds in large tracts. This is no mere theory, though advanced as such at first by some continental geologists, who have had the great satisfaction of seeing their theory adopted by practical men, and proved to be true, much coal being worked below the older beds that have been pushed above the Coal Measures by the overthrust faults.

Our trial-work, of course, does not yet lead us to consider such disturbances as those alluded to. We have at first to assume a normal succession of formations, and not to carry on explorations in beds that can be proved to be older than the Coal Measures; but the time may come when it will be otherwise.

Another matter to which attention has been drawn by our foreign friends is an apparent general persistence of disturbances along certain lines, or in other words, the recurrence of disturbances in newer beds in those parts where earlier movements had affected older beds; so that, reasoning backward, where we see marked signs of disturbance for long distances in beds at or near the surface, there we may expect to find pre-existing disturbances of the older beds beneath. This, however, is a somewhat controversial question, and much remains to be done on it; but should it be proved as a general rule it may have much effect on our underground coal.

Finally, the question of the possibility of finding and of work-

ing coal in various parts of south-eastern England is not merely of local interest; it is of national importance. The time must come when the coal-fields that we have worked for years will be more or less exhausted, and we ought certainly to look out ahead for others, so as to be ready for the lessening yield of those that have served us so well. It is on our coal that our national prosperity largely, one may say chiefly, depends, and, as far as we can see, will depend. Let us not neglect any of the bounteous gifts of nature, but let us show rather that we are ready to search for the treasures that may be hidden under our feet, and the finding of which will result in the continued welfare of our native land.

APPENDIX.—*List of the Chief Papers on the Old Rocks Underground in South-Eastern England since* 1889, *when the literature of the subject was treated of in the Memoir on the Geology of London, &c.*

Bertrand, Prof. M. Sur le Raccordement des Bassins houillers du Nord de la France et du Sud d l'Angleterre. *Annales des Mines* and *Trans. Fed. Inst. Min. Eng*, vol. v. (1893).

Brady F. Dover Coal Boring. Observations on the Correlation of the Franco-Belgian, Dover and Somerset Coal-fields (8vo. 1892). Second Issue, with Additions, 1893. Notice by E. Lorieux in *Annales des Mines*, 1892.

Dawkins, Prof. W. B. The Discovery of Coal near Dover, NATURE, vol. xli., pp. 418, 419; *Iron and Coal Trades Gazette; Contemporary Review*, vol. lvii. pp. 470–478. The Search for Coal in the South of England, *Proc. Roy. Inst.* (nine pages); NATURE, vol. xlii. pp. 319–322. The Discovery of Coal Measures near Dover, *Trans. Manchester Geol. Soc.*, vol. xx. pp. 502–517 (1890).

The Further Discovery of Coal at Dover and its Bearing on the Coal Question. *Trans. Manchester Geol. Soc.*, vol. xxi. pp. 456–474 (1892).

On the South-Eastern Coal-field at Dover, *Trans. Manchester Geol. Soc.*, vol. xxii. pp. 488–510: The Probable Range of the Coal Measures in Southern England, *Trans, Fed. Inst. Min. Eng.*, vol vii. (thirteen pages and plate) (1894).

Harrison, W. J. On the Search for Coal in the South East of England: with Special Reference to the Probability of the Existence of a Coal-field beneath Essex (twenty-eight pages and plate). 8vo. Birmingham (1894).

Irving, Rev. Dr. A. The Question of Workable Coal Measures beneath Essex. *Herts and Essex Observer*, July 14, 1894.

Martin, E. A. On the Underground Geology of London. *Science Gossip*, No. 335, pp. 251–254; No. 337, pp. 11–15 (1892, 1893).

Rücker, Prof. A. W., and Prof. T. E. Thorpe. Magnetic Survey of the British Isles, *Phil. Trans.*, vol. clxxxi. (see pp. 280, &c., and plate 14) (1891): A popular account by Prof. Rücker under the title Underground Mountains, *Good Words*, January to March 1890.

Topley, W. Coal in Kent. *Trans. Fed. Inst. Min. Eng.*, vol. i. pp. 376–387 (1892).

Whitaker, W. Coal in the South-East of England, *Journ. Soc. Arts*, vol. xxxviii. pp. 543–557: Suggestions on Sites for Coal-search in the South-East of England, *Geol. Mag.* dec. iii. vol. vii. pp. 514–516 (1890).

Whitaker, W., and A. J. Jukes-Browne. On Deep Borings at Culford and Winkfield, with Notes on those at Ware and Cheshunt, *Quart. Journ. Geol. Soc.*, vol. i. pp. 488–514 (1894).

The Eastern Counties' Coal Boring and Development Syndicate . . . Geological Reports by T. V. Holmes, J. E. Taylor, and W. Whitaker (fifteen pages, 8vo. Ipswich), (1893). Partly reprinted in *Essex Naturalist*.

Omitted from Notice in 1889.

Drew, F. Is there Coal under London? *Science for All*, vol. v. pp. 324–328.

Firket, A. Sur l'Extension en Angleterre du Bassin houiller Franco-Belge. *Ann. Soc. Géol. Belg.* t. x. *Bulletin*, pp. xcii.–xciv. (1883).

Taylor, W. On the Probability of Finding Coal in the South-East of England, pp. ii. 22 (8vo. Reigate), (1886).

Topley, W. On the Correspondence between some Areas of Apparent Upheaval and the Thickening of Subjacent Beds. *Quart. Journ. Geol. Soc*, vol. xxx. (see pp. 186, 190–195), (1874). See also Memoir "The Geology of the Weald," pp. 241, 242, pl. vi. (1875).

SECTION D.

ZOOLOGY.

OPENING ADDRESS BY WILLIAM A. HERDMAN, D.Sc., F.R.S., F.L.S., F.R.S E., PROFESSOR OF NATURAL HISTORY IN UNIVERSITY COLLEGE.

THIS year, for the first time in the history of the British Association, Section D meets without including in the range of its subject-matter the Science of Botany. Zoology now remains as the sole occupant of Section D—that "Fourth Committee of Sciences," as it was at first called, more than sixty years ago, when our subject was one of that group of biological sciences, the others being Botany, Physiology, and Anatomy. These allied sciences have successively left us. Like a prolific mother our Section has given rise one after another to the now independent Sections of Anthropology, Physiology, and Botany. Our subject-matter has been greatly restricted in scope, but it is still very wide—this year, when Section I, devoted to the more special physiology of the medical physiologist, does not meet, perhaps a little wider than it may be in other years, since we are on this occasion credited with the subject "Animal Physiology"—surely *always* an integral part of Zoology! It is to be hoped that this Section will always retain that general and comparative physiology which is inseparable from the study of animal form and structure. The late Waynflete Professor of Physiology at Oxford, in his Newcastle address to this Section, said "that every appreciable difference in structure corresponds to a difference of function" (Burdon-Sanderson, "British Association Report" for 1889), and his successor, the present Waynflete Professor, has shown us "how pointless is structure apart from function, and how baseless and unstable is function apart from structure" (Gotch, "Presidential Address to Liverpool Biological Society," vol. ix., 1894)—the "argument for the simultaneous examination of both" in that science of Zoology which we profess is, to my mind, irresistible.

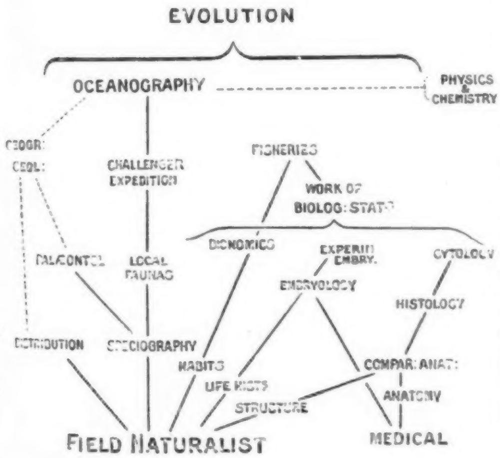
We include also in our subject-matter, besides the adult structure and the embryonic development of animals, their distribution both in space and time, the history and structure of extinct forms, speciography and classification, the study of the habits of animals and all that mass of lore and philosophy which has gathered around inquiries into instinct, breeding, and heredity. I trust that the discussion of matters connected with Evolution will always, to a large extent, remain with this Section D, which has witnessed in the past the addresses, papers, discussions, and triumphs of Darwin, Huxley, and Wallace.

When the British Association last met in Ipswich, in 1851, Section D, under the presidency of Prof. Henslow, still included Zoology, Botany, and Physiology, and a glance through the volumes of reports for that and neighbouring years recalls to us that our subject has undergone great and striking developments in the forty-four years that have elapsed. Zoology was still *pre-Darwinian* (though Charles Darwin was then in the thick of his epoch-making work—both what he calls his "plain barnacle work" and his "theoretic species work") (see "Life and Letters," vol. i. p. 380). Although the cell-theory had been launched a decade before, zoologists were not yet greatly concerned with those minute structural details which have since built up the science of Histology. The heroes of our science were then chiefly those glorious field naturalists, observers, and systematists who founded and established on a firm basis British Marine Zoology. Edward Forbes, Joshua Alder, Albany Hancock, were then in active work. George Johnston was at his zoophytes, Bowerbank at sponges, Busk at polyzoa. Forbes' short brilliant career was nearly run. He probably did more than any of his contemporaries to advance marine zoology. In the previous year, at the Edinburgh meeting of the Association, he and his friend MacAndrew had read their classic reports ("British Association Report" for 1850, p. 192—*et seq.*), "On the Investigation of British Marine Zoology by Means of the Dredge," and "On South European Marine Invertebrata," which mark the high-water level reached at that date, and for some time afterwards, in the exploration of our coasts and the explanation of the distribution of our marine animals. At the Belfast meeting, which followed Ipswich, Forbes exhibited his great map of the distribution of marine life in "Homoiozoic Belts." In November 1854 he was dead, six months after his appointment to the goal of his ambition, the professorship at Edinburgh, where, had he lived, there can be no doubt he would,

with his brilliant ability and unique personality, have founded a great school of Marine Zoology.

To return to the early fifties, Huxley—whose recent loss to science, to philosophy, to culture, we, in common with the civilised world, now deplore—at that time just returned from the memorable voyage of the *Rattlesnake*, was opening out his newly acquired treasures of comparative anatomy with papers on Siphonophora and on Sagitta, and one on the structure of Ascidians, in which he urged—fourteen years before Kowalevsky established it on embryological evidence in 1866—that their relations were with Amphioxus, as we now believe, rather than with the Polyzoa or the Lamellibranchiata, as had formerly been supposed. Bates was then on the Amazons, Wallace was just going out to the Malay Archipelago, Wyville Thomson, Hincks, and Carpenter, the successors of Forbes, Johnston, and Alder, were beginning their life-work. Abroad that great teacher and investigator, Johannes Müller, was training amongst his pupils the most eminent zoologists, anatomists, and physiologists of the succeeding quarter century. In this country, as we have seen, Huxley was just beginning to publish that splendid series of researches into the structure of nearly all groups in the animal kingdom, to which comparative anatomy owes so much.

In fact, the few years before and after the last Ipswich meeting witnessed the activity of some of the greatest of our British zoologists—the time was pregnant with work which has since advanced, and in some respects revolutionised our subject. It was then still usual for the naturalist to have a competent knowledge of the whole range of the natural sciences. Edward Forbes, for example, was a botanist and a geologist, as well as a zoologist. He occupied the chair of Botany at King's College, London, and the presidential chair of the Geological Section of the British Association at Liverpool in 1854. That excessive specialisation, from which most of us suffer in the present day, had not yet arisen; and in the comprehensive, but perhaps not very detailed, survey of his subject taken by one of the field naturalists of that time, we find the beginnings of different lines of work, which have since developed into some half-dozen distinct departments of zoology, are now often studied independently, and are in some real danger of losing touch with one another (see diagram).



The spendid anatomical and "morphological" researches of Huxley and Johannes Müller have been continued by the more minute histological or cellular work rendered possible by improvements of the microtome and the microscope, until at last in these latter years we investigate not merely the cellular anatomy of the body, but *the anatomy of the cell*—if indeed we are permitted to talk of "cell" at all, and are not rather constrained to express our results in terms of "cytomicrosomes," "somacules," or "idiosomes," and to regard our morphological unit, the cell, as a symbiotic community containing two colonies of totally dissimilar organisms (see Watasé in "Wood's Holl Biological Lectures," 1893). To such cytological investigations may well be applied Lord Macaulay's aphorism, "A point which yesterday was invisible is its goal to-day, and will be its starting-point to-morrow."

Somewhat similar advances in methods have led us from the life-histories studied of old to the new and fascinating science of embryology. The elder Milne-Edwards and Van Beneden knew that in their life-histories Ascidians produced tadpole-like young. Kowalevsky (1866) showed that in their embryonic stages these Ascidian tadpoles have the beginnings of their chief systems of organs formed in essentially the same manner and from the same embryonic layers as in the case of the frog's tadpole or any other typical young vertebrate; and now we are not content with less than tracing what is called the "cell-lineage" of such Ascidian embryos, so as to show the ancestry and descendants, the traditions, peculiarities of, and influences at work upon each of the embryonic cells—or areas of protoplasm—throughout many complicated stages. And there is now opening up from this a great new field of experimental and "mechanical" embryology, in which we seek the clue to the explanation of particular processes and changes by determining under what conditions they take place, and how they are affected by altered conditions. We are brought face to face with such curious problems as, Why does a frog's egg, in the two-celled stage, of which one-half has been destroyed, develop into half an embryo when it is kept with one (the black) surface uppermost, and into—not half an embryo, but—a whole embryo of *half the usual size* if kept with the other (the white) surface upwards. Apparently, according to the conditions of the experiment, we may get half embryos or whole embryos of half size from one of the first two cells of the frog's egg.[1]

One of the most characteristic studies of the older field naturalists, the observation of habits, has now become, under the influence of Darwinism, the "Bionomics" of the present day, the study of the relations between habit and structure and environment—a most fascinating and promising field of investigation, which may be confidently expected to tell us much in the future in regard to the competition between species, and the useful or indifferent nature of specific characters.

Other distinct lines of zoological investigation, upon which I shall not dwell, are geographical distribution and palæontology—subjects in which the zoologist comes into contact with, and may be of some service to his fellow-workers in geology. And there still remains the central avenue of the wide zoological domain—that of speciography and systematic zoology—which has been cultivated by the great classifiers and monographers from Linnæus to Hæckel, and has culminated in our times in the magnificent series of fifty quarto volumes, setting forth the scientific results of the *Challenger* Expedition; a voyage of discovery comparable only in its important and wide-reaching results with the voyages of Columbus, Gama and Magellan at the end of the fifteenth century. It is now so long since the *Challenger* investigations commenced that few I suppose outside the range of professional zoologists are aware that although the expedition took place in 1872 to 1876, the work resulting therefrom has been going on actively until now—for nearly a quarter of a century in all—and in a sense, and a very real one, will never cease, for the *Challenger* has left an indelible mark upon science, and will remain through the ages exercising its powerful, guiding influence, like the work of Aristotle, Newton, and Darwin.

Most of the authors of the special memoirs on the sea and its various kinds of inhabitants, have interpreted in a liberal spirit the instructions they received to examine and describe the collections entrusted to them, and have given us very valuable summaries of the condition of our knowledge of the animals in question, while some of the reports are little less than complete monographs of the groups. I desire to pay a tribute of respect to my former teacher and scientific chief, Sir Wyville Thomson, to whose initiative, along with Dr. W. B. Carpenter, we owe the first inception of our now celebrated deep-sea dredging expeditions, and to whose scientific enthusiasm, combined with administrative skill, is due in great part the successful accomplishment of the *Lightning*, the *Porcupine*, and the *Challenger* Expeditions. Wyville Thomson lived long enough to superintend the first examination of the collections brought home, their division into groups, and the allotment of these to specialists for description. He enlisted the services of his many scientific friends at home and abroad, he arranged the general plan of the work, decided upon the form of publication, and died in

[1] See Morgan, "Anat. Anzeig.," 1895, x. Bd. p. 623, and recent papers by Roux Hertwig, Born, and O. Schultze.

1882, after seeing the first ten or twelve zoological reports through the press.

Within the last few months have been issued the two concluding volumes of this noble series, dealing with a summary of the results, conceived and written in a masterly manner by the eminent editor of the reports, Dr. John Murray. An event of such first-rate importance in zoology as the completion of this great work ought not to pass unnoticed at this zoological gathering. I desire to express my appreciation and admiration of Dr. Murray's work, and I do not doubt that the Section will permit me to convey to Dr. Murray the congratulations of the zoologists present, and their thanks for his splendid services to science. Murray, in these "Summary" volumes, has given definiteness of scope and purpose, and a tremendous impulse, to that branch of science—mainly zoological—which is coming to be called

OCEANOGRAPHY.

Oceanography is the meeting ground of most of the sciences. It deals with botany and zoology, "including animal physiology"; chemistry, physics, mechanics, meteorology, and geology all contribute, and the subject is of course intimately connected with geography, and has an incalculable influence upon mankind, his distribution, characteristics, commerce, and economics. Thus oceanography, one of the latest developments of marine zoology, extends into the domain of, and ought to find a place in, every one of the Sections of the British Association.

Along with the intense specialisation of certain lines of zoology in the last quarter of the nineteenth century, it is important to notice that there are also lines of investigation which require an extended knowledge of, or at least make use of the results obtained from, various distinct subjects. One of these is oceanography, another is bionomics, which I have referred to above, a third is the philosophy of zoology, or all those studies which bear upon the theory of evolution, and a fourth is the investigation of practical fishery problems—which is chiefly an application of marine zoology. Of these four subjects—which while analytic enough in the detailed investigation of any particular problem, are synthetic in drawing together and making use of the various divergent branches of zoology and the neighbouring sciences—oceanography, bionomics, and the fisheries' investigation, are most closely related, and I desire to devote the remainder of this address to the consideration of some points in connection with their present position.

Dr. Murray, in a few only too brief paragraphs at the end of his detailed summary of the results of the *Challenger* Expedition, which I have alluded to above, states some of the views, highly suggestive and original, at which he has himself arrived from his unique experience. Some of his conclusions are very valuable contributions to knowledge, which will no doubt be adopted by marine zoologists. Others, I venture to think, are less sound and well founded, and will scarcely stand the test of time and further experience. But for all such statements, or even suggestions, we should be thankful. They do much to stimulate further research, they serve, if they can neither be refuted nor established, as working hypotheses; and even if they have to be eventually abandoned, we should bear in mind what Darwin has said as to the difference in their influence on science between erroneous facts and erroneous theories. "False facts are highly injurious to the progress of science, for they often endure long; but false views, if supported by some evidence, do little harm, for every one takes a salutary pleasure in proving their falseness; and when this is done, one path towards error is closed, and the road to truth is often at the same time opened" (Darwin, "The Descent of Man," second edit. 1882, p. 606).

With all respect for Murray's work, and fully conscious of my own temerity in venturing to differ from one who has had such an extended experience of the sea and its problems, I am constrained to express my disagreement with some of his conclusions. And I am encouraged to do so by the belief that Murray will rightly feel that the best compliment which zoologists can pay to his work is to give it careful, detailed consideration, and discuss it critically. He will, I am sure, join me in the hope that, whether his views or mine prove the false ones, we may be able, by their discussion, to close a "path towards error," and possibly open "the road to truth."

One of the points upon which Murray lays considerable stress, and to the elaboration of which he devotes a prominent position in his "General Observations on the Distribution of Marine Organisms," is the presence of what he has called a "mud-line" around coasts at a depth of about one hundred fathoms. It is the point "at which minute particles of organic and detrital matters in the form of mud begin to settle on the bottom of the ocean." He regards it as the great feeding ground, and a place where the fauna is most abundant, and from which there have hived off, so to speak, the successive swarms or migrations which have peopled other regions—the deep waters, the open sea, the shallow waters and the estuaries, fresh waters, and land. Murray thus gives to his mud-line both a present and an historic importance which can scarcely be surpassed in the economy of life on this globe. I take it that the historic and the present importance stand or fall together—that the evidence as to the origin of faunas in the past is derived from their distribution at the present day, and I am inclined to think that Murray's opinion as to the distribution of animals in regard to the mud-line is not entirely in accord with the experience of specialists, and is not based upon reliable statistics. Murray's own statement is ("*Challenger* Expedition, Summary," vol. ii. p. 1433):—"A depth is reached along the continental shores facing the great oceans immediately below which the conditions become nearly uniform in all parts of the world, and where the fauna likewise presents a great uniformity. This depth is usually not far above nor far below the 100-fathom line, and is marked out by what I have elsewhere designated as the *Mud-line*. . . . Here is situated the great feeding ground in the ocean . . ." and he then goes on (p. 1434) to enumerate the Crustaceans, such as species of *Calanus*, *Euchæta*, *Pasiphæa*, *Crangon*, *Calocaris*, *Pandalus*, *Hippolyte*, many amphipods, isopods, and immense numbers of schizopods, which swarm, with fishes and cephalopods, immediately over this mud deposit. Now I venture to think that the experience of some of those who have studied the marine zoology of our own coasts does not bear out this statement. In the first place, our experience in the Irish Sea is that mud may be found at almost any depth, but is very varied in its nature and in its source. There may even be mud laid down between tide marks in an estuary where a very considerable current runs. A deposit of mud may be due to the presence of an eddy or a sheltered corner in which the finer particles suspended in the water are able to sink, or it may be due to the wearing away of a limestone beach, or to quantities of alluvium brought down by a stream from the land, or to the presence of a submerged bed of boulder clay, or even, in some places, to the sewage and refuse from coast towns. Finally, there is the deep-water mud, a very stiff blue-grey substance which sets, when dried, into a firm clay, and this is, I take it, the mud of which Dr. Murray writes. But in none of these cases, and certainly not in the last mentioned, is there in my experience or in that of several other naturalists I have consulted, any rich fauna associated with the mud. In fact, I would regard mud as supporting a comparatively poor fauna as compared with other shallow water deposits.

For practical purposes, round our own British coasts, it is still convenient to make use of the zones of depth marked out by Forbes. The first of these is the "Littoral zone," the space between tide marks, characterised by the abundance of sea-weeds, belonging to the genera *Lichina*, *Fucus*, *Enteromorpha*, *Polysiphonia*, and others, and by large numbers of individuals belonging to common species of *Balanus*, *Mytilus*, *Littorina*, *Purpura*, and *Patella* amongst animals. The second zone is the "Laminarian," which extends from low-water mark to a depth of a few fathoms, characterised by the abundant growth of large sea-weeds belonging to the genera *Laminaria*, *Alaria*, and *Himanthalia*, and by the presence of the beautiful red sea-weeds (Florideæ). There is abundance of vegetable food, and animals of all groups swarm in this zone, the numbers both of species and of individuals being very great. The genera *Helcion*, *Trochus*, and *Lacuna* are characteristic molluscan forms in our seas. Next comes Forbes' "Coralline" zone, badly so named, extending from about ten to forty or fifty fathoms or so. Here we are beyond the range of the ordinary sea-weeds, but the calcareous, coral-like Nullipores are present in places in such abundance as to make up deposits covering the floor of the sea for miles. Hydroid zoophytes and polyzoa are also abundant, and it is in this zone that we find the shell-beds lying off our coasts, produced by great accumulations of species of *Pecten*, *Ostrea*, *Pectunculus*, *Fusus*, and *Buccinum*, and forming rich feeding grounds for many of our larger fishes. All groups of marine animals are well represented in this zone, and *Antedon*, *Ophiothrix*, *Ophioglypha*, *Ebalia*, *Inachus*, and *Eurynome*, may be mentioned as characteristic genera. Lastly, there is what may be appropriately called the zone of deep mud (although Forbes

did not call it so), extending from some fifty fathoms down to (in our seas) one hundred or so. The upper limit of this zone is Murray's mud-line. We come upon it in the deep fjord-like sea-lochs on the west of Scotland, and in the Irish Sea to the west of the Isle of Man.

Now of these four zones, my experience is that the last—that of the deep mud—has by far the poorest fauna both in species and in individuals. The mud has a *peculiar* fauna and one of great interest to the zoologist, but it is not a *rich* fauna. It contains some rare and remarkable animals not found elsewhere, such as *Calocaris macandreæ*, *Panthalis oerstedi*, *Lipobranchius jeffreysi*, *Brissopsis lyrifera*, *Amphiura chiajii*, *Isocardia cor*, and *Sagartia herdmani*; and a few striking novelties have been described from it of late years, but we have no reason to believe that the number of these is great compared with the number of animals obtained from shallower waters.

Dr. Murray not only insists upon the abundance of animals on the mud, and its importance as the great feeding ground and place of origin of life in the ocean, but he also (p. 1432) draws conclusions as to the relative numbers of animals taken by a single haul of the trawl in deep and shallow waters which can scarcely be received, I think, by marine zoologists without a protest. His statement runs (p. 1432): "It is interesting to compare single hauls made in the deep sea and in shallow water with respect to the number of different species obtained. For instance, at station 146 in the Southern Ocean, at a depth of 1375 fathoms the 200 specimens captured belonged to 59 genera and 78 species." That was with a 10-foot trawl dragged for at most two miles during at most two hours. Murray then goes on to say: "In depths less than 50 fathoms, on the other hand, I cannot find in all my experiments any record of such a variety of organisms in any single haul even when using much larger trawls and dragging over much greater distances." He quotes the statistics of the Scottish Fishery Board's trawlings in the North Sea, with a 25-foot trawl, to show that the average catch is 7·3 species of invertebrata and 8·3 species of fish, the greatest number of both together recorded in one haul being 29 species. Murray's own trawlings in the West of Scotland gave a much greater number of species, sometimes as many as 50, "still not such a great variety of animals as was procured in many instances by the *Challenger's* small trawl in great depths."

Now, in the first place, it is curious that Murray's own table on p. 1437, in which he shows that the "terrigenous" deposits lying along the shore-lines yield many more animals, both specimens and species, per haul, than do the "pelagic" deposits[1] at greater depths, such as red clays and globigerina oozes, seems directly opposed to the conclusion quoted above. In the second place, I am afraid that Dr. Murray has misunderstood the statistics of the Scottish Fishery Board when he quotes them as showing that only 7·3 or so species of invertebrates are brought up, on the average, in the trawl net. I happen to know from Mr. Thomas Scott, F.L.S., the naturalist who has compiled the statistics in question, and also from my own observations when on board the *Garland* on one of her ordinary trawling expeditions, that the invertebrata noted down on the station sheet are merely a few of the more conspicuous or in other ways noteworthy animals. No attempt is made—nor could possibly be made in the time—by the one naturalist who has to attend to tow-nets, water-bottle, the kinds, condition, food, &c., of the fish caught and other matters—to give anything like a complete or even approximate list of the species, still less the number of individuals, brought up in the trawl. I submit, therefore, that it is entirely misleading to compare those Scottish Fishery Board statistics, which were not meant for such a purpose, but only to give a rough idea of the fauna associated with the fish upon certain grounds, with the carefully elaborated results, worked out at leisure by many specialists in their laboratories, of a haul of the *Challenger's* trawl. Of Dr. Murray's own trawlings in the West of Scotland I cannot, of course, speak so positively; but I shall be surprised to learn that the results of each haul were as carefully preserved and as fully worked out by specialists as were the *Challenger* collections.

Lastly, on the next Liverpool Marine Biology Committee's dredging expedition in the Irish Sea after the appearance of Dr. Murray's volumes, I set myself to determine the species taken in a haul of the trawl for comparison with the *Challenger* numbers. The haul was taken on June 23, at 7 miles west from Peel, on the north bank, bottom sand and shells, depth 21 fathoms, with a trawl of only 4-foot beam, less than half the size of the *Challenger* one, and it was not down for more than twenty minutes. I noted down the species observed, and I filled two bottles with undetermined stuff which my assistant, Mr. Andrew Scott, and I examined the following day in the laboratory. Our list comes to at least 112 species, belonging to at least 103 genera.[1] I counted 120 duplicate specimens which, added to 112, gives 232 individuals, but there may well have been 100 more. This experience, then, is very different from Murray's, and gives far larger numbers in every respect—specimens, species, and genera—than even the *Challenger* deep-water haul quoted. I append my list of species,[2] and practised marine zoologists will, I think, see at a glance that it is nothing out of the way, that it is a fairly ordinary assemblage of not uncommon animals such as is frequently met with when dredging in the "coralline" zone. I am sure that I have taken better netfuls than this both in the Irish Sea and on the West of Scotland.

In order to get another case on different ground, not of my own choosing, on the first occasion after the publication of Dr. Murray's volumes, when I was out witnessing the trawling observations of the Lancashire Sea Fisheries steamer *John Fell*, I counted, with the help of my assistant, Mr. Andrew Scott, and the men on board, the results of the first haul of the shrimp trawl. It was taken at the mouth of the Mersey estuary, inside the Liverpool bar, on what the naturalist would consider very unfavourable ground, with a bottom of muddy sand, at a depth of 6 fathoms. The shrimp trawl ($1\frac{1}{2}$-inch mesh) was down for one hour, and it brought up over seventeen thousand specimens, referable to at least 39 species,[3] belonging to 34 genera. These numbers have been exceeded on many other hauls taken in the ordinary course of work by the Fisheries steamer in Liverpool Bay—for example, on this occasion the fish numbered 5943, and I have records of hauls on which the fish numbered over 20,000, and the total catch of individual animals must have been nearly 50,000. Can any of Dr. Murray's hauls on the deep mud beat these figures?

The conclusion, then, at which I arrive in regard to the distribution of animals in deep water and in water shallower than 50 fathoms, from my own experience and an examination of the *Challenger* results, is in some respects the reverse of Murray's. I consider that there are more species and more individuals in the shallower waters, that the deep mud as dredged has a poor fauna, that the "Coralline" zone has a much richer one, and that the "Laminarian" zone, where there is vegetable as well as animal food, has probably the richest of all.

In order to come to as correct a conclusion as possible on the matter, I have consulted several other naturalists in regard to the smaller groups of more or less free-swimming Crustacea, such as Copepoda and Ostracoda, which I thought might possibly be in considerable numbers over the mud. I have asked three well-known specialists on such Crustaceans—viz., Prof. G. S. Brady, F.R.S., Mr. Thomas Scott, F.L.S., and Mr. I. C. Thompson, F.L.S.—and they all agree in stating that, although interesting and peculiar, the Copepoda and Ostracoda from the deep mud are not abundant either in species or in individuals.

[1] One of the earliest of the *Challenger* oceanographic results, the classification of the submarine deposits into "terrigenous" and "pelagic," seems inadequate to represent fully the facts in regard to sea-bottoms, so I am proposing elsewhere ("Report of Irish Sea Committee") the following amended classification:—(1) Terrigenous (Murray), where the deposit is formed chiefly of mineral particles derived from the waste of the land; (2) Neritic, where the deposit is chiefly of organic origin, and is derived from the shells and other hard parts of the animals and plants living on the bottom; (3) Planktonic (Murray's "pelagic"), where the greater part of the deposit is formed of the remains of free-swimming animals and plants which lived in the sea over the deposit.

[1] It is interesting, in connection with Darwin's opinion that an animal's most formidable competitors in the struggle for existence are those of its own kind or closely allied forms, to notice the large proportion of genera to species in such hauls. I have noticed this in many lists, and it certainly suggests that closely related forms are comparatively rarely taken together.

[2] See *Appendix*, p. 501.

[3]

Solea vulgaris	*Mytilus edulis*	*Dactylopus rostratus*
Pleuronectes platessa	*Tellina tenuis*	*Cletodes limicola*
P. limanda	*Mactra stultorum*	*Caligus*, sp.
Gadus morrhua	*Fusus antiquus*	*Flustra foliacea*
G. æglefinus	*Carcinus mænas*	*Aphrodite aculeata*
G. merlangus	*Portunus*, sp.	*Pectinaria belgica*
Clupea spratta	*Eupagurus bernhardus*	*Nereis*, sp.
C. harengus	*Crangon vulgaris*	*Asterias rubens*
Trachinus vipera	*Sacculina*, sp.	*Hydractinia echinata*
Agonus cataphractus	Some Amphipoda	*Sertularia abietina*
Gobius minutus	*Longipedia coronata*	*Hydrallmania falcata*
Raia clavata	*Ectinosoma spinipes*	*Aurelia aurita*
R. maculata	*Sunaristes paguri*	*Cyanæa*, sp.

In answer to the question which of the three regions (1) the littoral zone, (2) from low water to 20 fathoms, and (3) from 20 fathoms onwards, is richest in small free-swimming, but bottom-haunting, Crustacea, they all replied the middle region from 0 to 20 fathoms, which is the Laminarian zone and the upper edge of the Coralline. Prof. Brady assures me that nearly every other kind of bottom and locality is better than mud for obtaining Ostracoda. Mr. T. Scott considers that Ostracoda are most abundant in shallow water, from 5 to 20 fathoms. He tells me that as the result of his experience in Loch Fyne, where a great part of the loch is deep, the richest fauna is always where banks occur, coming up to about 20 fathoms, and having the bottom formed of sand, gravel and shells. The fauna on and over such banks, which are in the Coralline zone, is much richer than on the deeper mud around them. On an ordinary shelving shore on the west coast of Scotland Mr. Scott, who has had great experience in collecting, considers that the richest fauna is usually at about 20 fathoms. My own experience in dredging in Norway is the same. In the centre of the fjords in deep water on the mud there are rare forms, but very few of them, while in shallower water at the sides, above the mud, on gravel, shells, rock, and other bottoms, there is a very abundant fauna.

Probably no group of animals in the sea is of so much importance from the point of view of food as the Copepoda. They form a great part of the food of whales, and of herrings and many other useful fish, both in the adult and in the larval state, as well as of innumerable other animals, large and small. Consequently, I have inquired somewhat carefully into their distribution in the sea, with the assistance of Prof. Brady, Mr. Scott, and Mr. Thompson. These experienced collectors all agree that Copepoda are most abundant, both as to species and individuals, close round the shore, amongst seaweeds, or in shallow water in the Laminarian zone over a weedy bottom. Individuals are sometimes extremely abundant on the surface of the sea amongst the plankton, or in shore pools near high water, where, amongst *Enteromorpha*, they swarm in immense profusion; but, for a gathering rich in individuals, species, and genera, the experienced collector goes to the shallow waters of the Laminarian zone. In regard to the remaining, higher, groups of the Crustacea my friend, Mr. Alfred O. Walker, tells me that he considers them most abundant at depths of 0 to 20 fathoms.

I hope no one will think that these are detailed matters interesting only to the collector, and having no particular bearing upon the great problems of biology. The sea is admittedly the starting-point of life on this earth, and the conclusions we come to as to the distribution of life in the different zones must form and modify our views as to the origin of the faunas—as to the peopling of the deep sea, the shallow waters, and the land. Murray supposes that life started in Pre-Cambrian times on the mud, and from there spread upwards into shallower waters, outwards on to the surface, and, a good deal later, downwards to the abysses by means of the cold polar waters. The late Prof. Moseley considered the pelagic, or surface life of the ocean to be the primitive life from which all the others have been derived. Prof. W. K. Brooks ("The Genus Salpa," 1893, p. 156, &c.) considers that there was a primitive pelagic fauna, consisting of the simplest microscopic plants and animals, and "that pelagic life was abundant for a long period during which the bottom was uninhabited."

I, on the other hand, for the reasons given fully above, consider that the Laminarian zone close to low-water mark is at present the richest in life, that it probably has been so in the past, and that if one has to express a more definite opinion as to where, in Pre-Cambrian times, life in its simplest forms first appeared, I see no reason why any other zone should be considered as having a better claim than what is now the Laminarian to this distinction. It is there, at present at any rate, in the upper edge of the Laminarian zone, at the point of junction of sea, land, and air, where there is a profusion of food, where the materials brought down by streams or worn away from the land are first deposited, where the animals are able to receive the greatest amount of light and heat, oxygen and food, without being exposed periodically to the air, rain, frost, sun, and other adverse conditions of the littoral zone, it is there that life—it seems to me—is most abundant, growth most active, competition most severe. It is there, probably, that the surrounding conditions are most favourable to animal life; and, therefore, it seems likely that it is from this region that, as the result of overcrowding, migrations have taken place downwards to the abysses, outwards on the surface, and upwards on to the shore. Finally, it is in this Laminarian zone, probably, that under the stress of competition between individuals and between allied species evolution of new forms by means of natural selection has been most active. Here, at any rate, we find, along with some of the most primitive of animals, some of the most remarkably modified forms, and some of the most curious cases of minute adaptation to environment. This brings us to the subject of

BIONOMICS,

which deals with the habits and variations of animals, their modifications, and the relations of these modifications to the surrounding conditions of existence.

It is remarkable that the great impetus given by Darwin's work to biological investigation has been chiefly directed to problems of structure and development, and not so much to bionomics until lately. Variations amongst animals in a state of nature is, however, at last beginning to receive the attention it deserves. Bateson has collected together, and classified in a most useful book of reference, the numerous scattered observations on variation made by many investigators, and has drawn from some of these cases a conclusion in regard to the discontinuity of variation which many field zoologists find it hard to accept.

Weldon and Karl Pearson have recently applied the methods of statistics and mathematics to the study of individual variation. This method of investigation, in Prof. Weldon's hands, may be expected to yield results of great interest in regard to the influence of variations in the young animal upon the chance of survival, and so upon the adult characteristics of the species. But while acknowledging the value of these methods, and admiring the skill and care with which they have been devised and applied, I must emphatically protest against the idea which has been suggested, that only by such mathematical and statistical methods of study can we successfully determine the influence of the environment on species, gauge the utility of specific characters, and throw further light upon the origin of species. For my part, I believe we shall gain a truer insight into those mysteries which still involve variations and species by a study of the characteristic features of individuals, varieties, and species in a living state in relation to their environment and habits. The mode of work of the old field naturalists, supplemented by the apparatus and methods of the modern laboratory, is, I believe, not only one of the most fascinating, but also one of the most profitable fields of investigation for the philosophical zoologist. Such studies must be made in that modern outcome of the growing needs of our science, the Zoological Station, where marine animals can be kept in captivity under natural conditions, so that their habits may be closely observed, and where we can follow out the old precept—first, observation and reflection; then experiment.

The biological stations of the present day represent, then, a happy union of the field work of the older naturalists with the laboratory work of the comparative anatomist, histologist, and embryologist. They are the culmination of the "Aquarium" studies of Kingsley and Gosse, and of the feeling in both scientific men and amateurs, which was expressed by Herbert Spencer when he said: "Whoever at the seaside has not had a microscope and an aquarium has yet to learn what the highest pleasures of the seaside are." Moreover, I feel that the biological station has come to the rescue, at a critical moment, of our laboratory worker who, without its healthy, refreshing influence, is often in these latter days in peril of losing his intellectual life in the weary maze of microtome methods and transcendental cytology. The old Greek myth of the Libyan giant, Antæus, who wrestled with Hercules and regained his strength each time he touched his mother earth, is true at least of the zoologist. I am sure he derives fresh vigour from every direct contact with living nature.

In our tanks and artificial pools we can reproduce the Littoral and the Laminarian zones; we can see the methods of feeding and breeding—the two most powerful factors in influencing an animal. We can study mimicry, and test theories of protective and warning colouration.

The explanations given by these theories of the varied forms and colours of animals were first applied by such leaders in our science as Bates, Wallace, and Darwin, chiefly to insects and birds, but have lately been extended, by the investigations of Giard, Garstang, Clubb, and others, to the case of marine animals. I may mention very briefly one or two examples. Amongst the Nudibranchiate Mollusca—familiar animals around

most parts of our British coasts—we meet with various forms which are edible, and, so far as we know, unprotected by any defensive or offensive apparatus. Such forms are usually shaped or coloured so as to resemble more or less their surroundings, and so become inconspicuous in their natural haunts. *Dendronotus arborescens*, one of the largest and most handsome of our British Nudibranchs, is such a case. The large, branched processes on its back, and its rich purple-brown and yellow markings, tone in so well with the masses of brown and yellow zoophytes and purplish-red seaweeds, amongst which we usually find *Dendronotus*, that it becomes very completely protected from observation; and, as I know from my own experience, the practised eye of the naturalist may fail to detect it lying before him in the tangled forests of a shore-pool.

Other Nudibranchs, however, belonging to the genus *Eolis* for example, are coloured in such a brilliant and seemingly crude manner, that they do not tone in with any natural surroundings, and so are always conspicuous. They are active in their habits, and seem rather to court observation than to shun it. When we remember that such species of *Eolis* are protected by the numerous stinging cells in the cnidophorous sacs placed on the tips of all the dorsal processes, and that they do not seem to be eaten by other animals, we have at once an explanation of their fearless habits and of their conspicuous appearance. The brilliant colours are in this case of a warning nature, for the purpose of rendering the animal provided with the stinging cells noticeable and recognisable. But it must be remembered that in a museum jar, or in a laboratory dish, or as an illustration in a book or on the wall, *Dendronotus* is quite as conspicuous and striking an animal as *Eolis*. In order to interpret correctly the effect of their forms and colours, we must see them alive and at home, and we must experiment upon their edibility or otherwise in the tanks of our biological stations.[1]

Let me give you one more example of a somewhat different kind. The soft, unprotected mollusc, *Lamellaria perspicua*, is not uncommonly found associated (as Giard first pointed out) with colonies of the compound Ascidian *Leptoclinum maculatum*, and in these cases the *Lamellaria* is found to be eating the *Leptoclinum*, and lies in a slight cavity which it has excavated in the Ascidian colony, so as to be about flush with the general surface. The integument of the mollusc is, both in general tint and also in surface markings, very like the Ascidian colony with its scattered ascidiozooids. This is clearly a good case of protective colouring. Presumably the *Lamellaria* escapes the observation of its enemies through being mistaken for a part of the *Leptoclinum* colony; and the *Leptoclinum*, being crowded like a sponge with minute sharp-pointed spicules, is, I suppose, avoided as inedible by carnivorous animals, which might devour such things as the soft unprotected mollusc. But the presence of the spicules evidently does not protect the *Leptoclinum* from *Lamellaria*, so that we have, if the above interpretation is correct, the curious result that the *Lamellaria* profits by a protective characteristic of the *Leptoclinum*, for which it has itself no respect, or, to put it another way, the *Leptoclinum* is protected against enemies to some extent for the benefit of the *Lamellaria*, which preys upon its vitals.

It is, to my mind, no sufficient objection to theories of protective and warning colouration that careful investigation may from time to time reveal cases where a disguise is penetrated, a protection frustrated, an offensive device supposed to confer inedibility apparently ignored. We must bear in mind that the enemies, as well as their prey, are exposed to competition, are subject to natural selection, are undergoing evolution; that the pursuers and the pursued, the eaters and the eaten, have been evolved together; and that it may be of great advantage to be protected from *some*, even if not from all enemies. Just as on land, some animals can browse upon thistles whose "nemo me impune lacessit" spines are supposed to confer immunity from attack, so it is quite in accord with our ideas of evolution by means of natural selection to suppose that some marine animals have evolved an indifference to the noxious sponge or to the bristling Ascidian, which are able, by their defensive characteristics, like the thistle, to repel the majority of invaders.

Although we can keep and study the Littoral and Laminarian animals at ease in our zoological stations, it may perhaps be questioned how far we can reproduce in our experimental and observational tanks the conditions of the "Coralline" and the "Deep-mud" zones. One might suppose that the pressure —which we have no means as yet for supplying[1]—and which at 30 fathoms amounts to nearly 100 lbs. on the square inch, and at 80 fathoms to about 240 lbs., or over 2 cwt. on the square inch, would be an essential factor in the life conditions of the inhabitants of such depths, and yet we have kept half a dozen specimens of *Calocaris macandreæ*, dredged from 70 to 80 fathoms, alive at the Port Erin Biological Station for several weeks; we have had both the red and the yellow forms of *Sarcodictyon catenata*, dredged from 30 to 40 fathoms, in a healthy condition with the polypes freely expanded for an indefinite period; and Mr. Arnold Watson has kept the Polynoid worm, *Panthalis oerstedi*, from the deep mud at over 50 fathoms, alive, healthy, and building its tube under observation, first for a week at the Port Erin Station, and then for many months at Sheffield in a comparatively small tank with no depth of water. Consequently it seems clear that, with ordinary care, almost any marine animals from such depths as are found within the British area may be kept under observation and submitted to experiment in healthy and fairly natural conditions. The Biological Station, with its tanks, is in fact an arrangement whereby we bring a portion of the sea with its rocks and bottom deposits and seaweeds, with its inhabitants and their associates, their food and their enemies, and place it for continuous study on our laboratory table. It enables us to carry on the bionomical investigations to which we look for information as to the methods and progress of evolution; in it lie centred our hopes of a comparative physiology of the invertebrates—a physiology not wholly medical—and finally to the Biological Station we confidently look for help in connection with our coast fisheries. This brings me to the last subject which I shall touch upon, a subject closely related both to Oceanography and Bionomics, and one which depends much for its future advance upon our Biological Stations—that is the subject of

AQUICULTURE,

or industrial Ichthyology, the scientific treatment of fishery investigations, a subject to which Prof. M'Intosh has first in this country directed the attention of zoologists, and in which he has been guiding us for the last decade by his admirable researches. What chemistry is to the aniline, the alkali, and some other manufactures, marine zoology is to our fishing industries.

Although zoology has never appealed to popular estimation as a directly useful science having industrial applications in the same way that Chemistry and Physics have done, and consequently has never had its claims as a subject of technical education sufficiently recognised; still, as we in this Section are well aware, our subject has many technical applications to the arts and industries. Biological principles dominate medicine and surgery. Bacteriology, brewing, and many allied subjects are based upon the study of microscopic organisms. Economic entomology is making its value felt in agriculture. Along all these and other lines there is a great future opening up before biology, a future of extended usefulness, of popular appreciation, and of value to the nation—and not the least important of these technical applications will, I am convinced, be that of zoology to our fishing industries. When we consider their enormous annual value—about eight millions sterling at first hand to the fisherman, and a great deal more than that by the time the products reach the British public, when we remember the very large proportion of our population who make their living directly or indirectly (as boatbuilders, net-makers, &c.) from the fisheries, and the still larger proportion who depend for an important element in their food supply upon these industries; when we think of what we pay other countries—France, Holland, Norway—for oysters, mussels, lobsters, &c., which we could rear in this country if our sea-shores and our sea-bottom were properly cultivated; and when we remember that fishery cultivation or aquiculture is applied zoology, we can readily realise the enormous value to the nation which this direct application of our science will one day have—perhaps I ought rather to say, we can *scarcely* realise the extent to which zoology may be made the guiding science of a great national industry. The flourishing shellfish industries of France, the oyster culture at Arcachon and Marennes, and the mussel culture by bouchots in the Bay of Aiguillon, show what can be done as the result of encouragement and wise assistance from Government, with constant

[1] See my experiments on Fishes with Nudibranchs, in *Trans. Biol. Soc., Liverpool*, vol. iv. p. 150; and NATURE for June 26, 1890.

[1] Following up M. Regnard's experiments, some mechanical arrangement whereby water could be kept circulating and aerated under pressure in closed tanks might be devised, and ought to be tried at some zoological station. I learn from the Director at the Plymouth Station that some of the animals from deep water, such as Polyzoa, do not expand in their tanks.

industry on the part of the people, directed by scientific knowledge. In another direction the successful hatching of large numbers (hundreds of million) of cod and plaice by Captain Dannevig in Norway, and by the Scottish Fishery Board at Dunbar, opens up possibilities of immense practical value in the way of restocking our exhausted bays and fishing banks—depleted by the over-trawling of the last few decades.

The demand for the produce of our seas is very great, and would probably pay well for an increased supply. Our choicer fish and shellfish are becoming rarer, and the market prices are rising. The great majority of our oysters are imported from France, Holland, and America. Even in mussels we are far from being able to meet the demand. In Scotland alone the long line fishermen use nearly a hundred millions of mussels to bait their hooks every time the lines are set, and they have to import annually many tons of these mussels at a cost of from £3 to £3 10s. a ton. . . .

Whether the wholesale introduction of the French method of mussel culture, by means of bouchots, on to our shores would be a financial success is doubtful. Material and labour are dearer here, and beds, scars, or scalps seem, on the whole, better fitted to our local conditions; but as innumerable young mussels all round our coast perish miserably every year for want of suitable objects to attach to, there can be no reasonable doubt that the judicious erection of simple stakes or plain bouchots would serve a useful purpose, at any rate in the collection of seed, even if the further rearing be carried on by means of the bed system.

All such aquicultural processes require, however, in addition to the scientific knowledge, sufficient capital. They cannot be successfully carried out on a small scale. When the zoologist has once shown as a laboratory experiment, in the zoological station, that a particular thing can be done—that this fish can be hatched or that shellfish reared under certain conditions which promise to be an industrial success, then the matter should be carried out by the Government[1] or by capitalists on a sufficiently large scale to remove the risk of results being vitiated by temporary accident or local variation in the conditions. It is contrary, however, to our English traditions for Government to help in such a matter, and if our local Sea Fisheries Committees have not the necessary powers nor the available funds, there remains a splendid opportunity for opulent landowners to erect sea-fish hatcheries on the shores of their estates, and for the rich merchants of our great cities to establish aquiculture in their neighbouring estuaries, and by so doing, instruct the fishing population, resuscitate the declining industries, and cultivate the barren shores—in all reasonable probability to their own ultimate profit.

In addition to the farming of our shores there is a great deal to be done in promoting the fishing industries on the inshore and offshore grounds along our coast, and in connection with such work the first necessity is a thorough scientific exploration of our British seas by means of a completely fitted dredging and trawling expedition. Such exploration can only be done in little bits, spasmodically, by private enterprise. From the time of Edward Forbes it has been the delight of British marine zoologists to explore, by means of dredging from yachts or hired vessels during their holidays, whatever areas of the neighbouring seas were open to them. Some of the greatest names in the roll of our zoologists, and some of the most creditable work in British zoology, will always be associated with dredging expeditions. Forbes, Wyville Thomson, Carpenter, Gwyn Jeffreys, M'Intosh, and Norman—one can scarcely think of them without recalling—

> "Hurrah for the dredge, with its iron edge,
> And its mystical triangle,
> And its hided net, with meshes set,
> Odd fishes to entangle!"[2]

Much good pioneer work in exploration has been done in the past by these and other naturalists, and much is now being done locally by committees or associations—by the Dublin Royal Society on the West of Ireland, by the Marine Biological Association at Plymouth, by the Fishery Board in Scotland, and by the Liverpool Marine Biology Committee in the Irish Sea; but few zoologists or zoological committees have the means, the opportunity, the time to devote—along with their professional duties—to that detailed systematic survey of our whole British sea-area which is really required. Those who have not had experience of it can scarcely realise how much time, energy, and money it requires to keep up a series of dredging expeditions, how many delays, disappointments, expensive accidents and real hardships there are, and how often the naturalist is tempted to leave unprofitable ground, which ought to be carefully worked over, for some more favoured spot where he knows he can count upon good spoil. And yet it is very necessary that the whole ground—good or bad though it may be from the zoological point of view—should be thoroughly surveyed, physically and biologically, in order that we may know the conditions of existence which environ our fishes, on their feeding grounds, their spawning grounds, their "nurseries," or wherever they may be.

The British Government has done a noble piece of work which will redound to its everlasting credit in providing for, and carrying out, the *Challenger* expedition. Now that that great enterprise is completed, and that the whole scientific world is united in appreciation of the results obtained, it would be a glorious consequence, and surely a very wise action in the interests of the national fisheries, for the Government to fit out an expedition, in charge of two or three zoologists and fisheries experts, to spend a couple of years in exploring more systematically than has yet been done, or can otherwise be done, our British coasts from the Laminarian zone down to the deep mud. No one could be better fitted to organise and direct such an expedition than Dr. John Murray.

Such a detailed survey of the bottom and the surface waters, of their conditions and their contents, at all times of the year for a couple of years, would give us the kind of information we require for the solution of some of the more difficult fishery problems—such as the extent and causes of the wanderings of our fishes, which "nurseries" are supplied by particular spawning grounds, the reason of the sudden disappearance of a fish such as the haddock from a locality, and in general the history of our food fishes throughout the year. It is creditable to our Government to have done the pioneer work in exploring the great ocean, but surely it would be at least equally creditable to them—and perhaps more directly and immediately profitable, if they look for some such return from scientific work—to explore our own seas and our own sea-fisheries.

There is still another subject connected with the fisheries which the the biologist can do much to elucidate—I mean the diseases of edible animals and the effect upon man of the various diseased conditions. It is well known that the consumption of mussels taken from stagnant or impure water is sometimes followed by severe symptoms of irritant poisoning which may result in rapid death. This "musselling" is due to the presence of an organic alkaloid or ptomaine, in the liver of the mollusc, formed doubtless by a micro-organism in the impure water. It is clearly of the greatest importance to determine accurately under what conditions the mussel can become infected by the micro-organism, in what stage it is injurious to man, and whether, as is supposed, steeping in pure water with or without the addition of carbonate of soda will render poisonous mussels fit for food.

During this last year there has been an outcry, almost amounting to a scare, and seriously affecting the market,[1] as to the supposed connection between oysters taken from contaminated water and typhoid fever. This, like the musselling, is clearly a case for scientific investigation, and, with my colleague, Prof. Boyce, I have commenced a series of experiments and observations, partly at the Port Erin Biological Station, where we have oysters laid down on different parts of the shore under very different conditions, as well as in dishes and tanks, and partly at University College, Liverpool.

Our object is to determine the effect of various conditions of water and bottom upon the life and health of the oyster, the effect of the addition of various impurities to the water, the conditions under which the oyster becomes infected with the typhoid bacillus, and the resulting effect upon the oyster, the period during which the oyster remains infectious, and lastly, whether any simple practicable measures can be taken (1) to determine whether an oyster is infected with typhoid, and (2) to render such an oyster innocuous to man. As Prof. Boyce and I propose to lay a paper upon this subject before the Section, I shall not occupy further time now by a statement of our methods and results.

I have probably already sufficiently indicated to you the extent and importance of the applications of our science to

[1] We require in England a Central Board or Government Department of Fisheries, composed in part of scientific experts, and that not merely for the purpose of imposing and enforcing regulations, but still more, in order that research into Fisheries problems may be instituted and aquicultural experiments carried out.

[2] The dredging song (see "Memoir of Edward Forbes," p. 247).

[1] I am told that between December and March the oyster trade decreased 75 per cent.

practical questions connected with our fishing industries. But if the zoologist has great opportunities for usefulness, he ought always to bear in mind that he has also grave responsibilities in connection with fisheries investigations. Much depends upon the results of his work. Private enterprise, public opinion, local regulations, and even imperial legislation, may all be affected by his decisions. He ought not lightly to come to conclusions upon weighty matters. I am convinced that of all the varied lines of research in modern zoology, none contains problems more interesting and intricate than those of bionomics, oceanography, and the fisheries, and of these three series the problems connected with our fisheries are certainly not the least interesting, not the least intricate, and not the least important in their bearing upon the welfare of mankind.

APPENDIX.

List of Species taken in one haul, on June 23, 1895 (see p. 497).

SPONGES:

Reniera, sp.
Halichondria, sp.
Cliona celata
Suberites domuncula
Chalina oculata

COELENTERATA:

Dicoryne conferta
Halecium halecinum
Sertularia abietina
Coppinia arcta
Hydrallmania falcata
Campanularia verticillata
Lafoea dumosa
Antennularia ramosa
Alcyonium digitatum
Virgularia mirabilis
Sarcodictyon catenata
Sagartia, sp.
Adamsia palliata

ECHINODERMATA:

Cucumaria, sp.
Thyone fusus
Asterias rubens
Solaster papposus
Stichaster roseus
Porania pulvillus
Palmipes placenta
Ophiocoma nigra
Ophiothrix fragilis
Amphiura chiajii
Ophioglypha ciliata
O. albida
Echinus sphæra
Spatangus purpureus
Echinocardium cordatum
Brissopsis lyrifera
Echinocyamus pusillus

VERMES:

Nemertes neesii
Chætopterus, sp.
Spirorbis, sp.
Serpula, sp.
Sabella, sp.
Owenia filiformis
Aphrodite aculeata
Polynoë, sp.

CRUSTACEA:

Scalpellum vulgare
Balanus, sp.
Cyclopicera nigripes
Acontiophorus elongatus
Artotrogus magniceps
Dyspontius striatus
Zaus goodsiri
Laophonte thoracica
Stenhelia reflexa
Lichomolgus forficula
Anonyx, sp.
Galathea intermedia
Munida bamffica
Crangon spinosus
Stenorhynchus rostratus
Inachus dorsettensis
Hyas coarctatus
Xantho tuberculatus
Portunus pusillus
Eupagurus bernhardus
E. prideauxii
E. cuanensis
Eurynome aspera
Ebalia tuberosa

POLYZOA:

Pedicellina cernua
Tubulipora, sp.
Crisia cornuta
Cellepora pumicosa, and three or four undetermined species of Lepralids
Flustra securifrons
Scrupocellaria reptans
Cellularia fistulosa

MOLLUSCA:

Anomia ephippium
Ostrea edulis
Pecten maximus
P. opercularis
P. tigrinus
P. pusio
Mytilus modiolus
Nucula nucleus
Cardium echinatum
Lissocardium norvegicum
Cyprina islandica
Solen pellucidus
Venus gallina
Lyonsia norvegica
Scrobicularia prismatica
Astarte sulcata
Modiolaria marmorata
Saxicava rugosa
Chiton, sp.
Dentalium entale
Emarginula fissura
Velutina lævigata
Turritella terebra
Natica alderi
Fusus antiquus
Aporrhais pespelicani
Oscanius membranaceus
Doris, sp.
Eolis coronata
Tritonia plebeia

TUNICATA:

Ascidiella virginea
Styelopsis grossularia
Eugyra glutinans
Botryllus, sp.
B., sp.

SECTION G.

MECHANICAL SCIENCE.

OPENING ADDRESS BY L. F. VERNON-HARCOURT, M.A., M.INST.C.E.

The Relation of Engineering to Science.

THE selection of a subject for an inaugural address, necessitated by the honour conferred upon me of presiding over this Section, has been rendered peculiarly difficult, both on account of the numerous able addresses delivered in past years by my eminent predecessors in this office, and also by the circumstance that the branches of engineering to which most of my professional life has been devoted have not as intimate a connection with mechanical science as some others. Moreover, whilst former Presidents of Section G have frequently dealt, in their addresses, with the progress of those special branches of engineering in which they have had most practical experience, such a course, in the present instance, would have exposed me to the danger of merely repeating information and reiterating opinions already recorded in the *Proceedings* of the Institution of Civil Engineers, and in other publications, with reference to maritime and hydraulic engineering. It has, accordingly, appeared to me that the exceptional occasion of addressing a gathering of scientific persons, and of engineers who testify their interest in science by attending these meetings, would be best utilised by considering the relation that engineering in general, and maritime and hydraulic engineering in particular, bear to pure science, and the means by which progress in engineering science might be best promoted, and its scope and utility increased.

In addition to the oft-quoted definition of civil engineering as "the art of directing the great sources of power in nature for the use and convenience of man," Thomas Tredgold also defined it, in 1828, as "that practical application of the most important principles of natural philosophy which has, in a considerable degree, realised the anticipations of Bacon and changed the aspect and state of affairs in the whole world." If the influence of engineering could be thus described in 1828, when railways and steamships were in their infancy and the electric telegraph and the various modern applications of electricity and magnetism had not come into existence, how far more true is it at the present day, when the various branches of engineering have attained such a marvellous development! Tredgold also realised, at that early date, that the resources of the engineer must be further directed so as to cope with the injurious forces of nature, such as floods, storms, and unsanitary conditions, and thus protect men from harm as well as promote their well-being. Moreover, he foresaw the great capabilities of development possessed by engineering, and its dependence on science; for he stated that "the real extent to which civil engineering may be applied is limited only by the progress of science; its scope and utility will be increased with every discovery in philosophy, and its resources with every invention in mechanical or chemical art, since its bounds are unlimited, and equally so must be the researches of its professors." If the full significance of these statements may be accepted as correct, engineers might fairly claim to have a right to say, "As engineers we are necessarily men of science, and no branch of science is outside our province." It might, however, be said that no engineer, with his absorbing professional avocations, would have the time to acquire even the rudiments of the principal branches of science, with their ever-increasing developments, to the study of each of which the life-work of many earnest searchers into the secrets of nature is wholly devoted. Nevertheless, a few branches of science, such as physiology, biology, and botany, appear to be beyond the scope of practical engineering; whilst a moderate acquaintance with some others might suffice for the needs of the engineer, except in certain special branches, supplemented, as it can readily be, by the advice of a specialist in complicated cases.

Among the branches of science necessary for the engineer, two may be regarded as of the highest importance, namely, mathematics and physics, upon which the science of engineering mainly depends; and without an adequate knowledge of these, no person should be able at the present day to enter the profession of a civil engineer. Other sciences of considerable, though of comparatively minor, importance to engineers in general, are chemistry, geology, and meteorology; but each of these assumes an enhanced value in special branches of engineering.

Mathematics in Relation to Engineering.—The pre-eminent importance of mathematics in relation to engineering may be accepted as fully established; and a President of the Institution of Civil Engineers would not now tell a pupil, at their first interview, that he had done very well without mathematics, a remark made to me by a justly celebrated engineer over thirty years ago.

Surveying, which is the handmaid of civil engineering, depends upon the principles of geometry for its accuracy; and ordinary triangulation, geodesy, and the rapid method of surveying and taking levels in rough country, known as tacheometry, are based on trigonometry and aided by logarithms. Tacheometry, indeed, though carried out by means of a specially constructed theodolite, may be regarded as the practical application of the familiar problem in trigonometry of finding the height and distance of an inaccessible tower. A proposition of Euclid forms the basis of the simplest and speediest method of setting out circular curves for railways; whilst astronomy has been resorted to for facilitating surveying in unexplored regions. The laws of statics are involved in the design of bridges, especially those of large span, and also of masonry dams, roofs, floors, columns, and other structures; whilst torsion, internal ballistics, the trajectory of a projectile, the forces of impact, and the stoppage of a railway train are dynamical problems. Hydrostatics and hydrodynamics provide the foundation of hydraulic engineering; though, owing to the complicated nature of the flow of water, observations and experiments have been necessary for obtaining correct formulæ of discharge. Geometrical optics has been employed for determining the forms of the lenses for giving a parallel direction to the rays proceeding from the lamps of a lighthouse, in accordance with the principles laid down by Fresnel. The theory of the tides, the tide tables giving the predicted tidal rise at the principal ports, and wave motion—questions of considerable importance to the harbour engineer—depend upon mathematical and astronomical calculations; whilst the stability and rolling of ships, the lines for a vessel of least resistance in passing through water, and the dimensions and form of screw-propellers, to obtain the greatest speed with a given expenditure of power, have been determined by mathematical considerations aided by experiment. Electrical engineering depends very largely upon mathematical and physical problems, guided by the results of practical experience; and the possibility of the commercial success of the first Atlantic cable, depending upon the rate of transmission of the signals and the loss of electrical intensity in that long journey, has been shown by Dr. John Hopkinson in his "James Forrest" lecture, to have been determined by Lord Kelvin by the solution of a partial differential equation (*Proceedings Inst. C.E.* vol. cxviii. p. 339).

All branches of applied mathematics have, accordingly, been utilised by engineers, or, as in the case of several general principles and tidal calculations, by mathematicians to their benefit; but graphic statics will probably gradually supersede analytical methods for the calculation of stresses, as more rapid in operation, and less subject to errors, which are also more easily detected in graphic diagrams. Pure mathematics, in its higher branches, appears to have a less direct connection with engineering; but applied mathematics is so largely dependent upon pure mathematics, that the latter, including the calculus and differential equations, cannot be safely neglected by the engineer, though certain branches, as, for instance, probabilities, the theory of numbers, the tracing of curves, and some of the more abstruse portions of the subject, may be dispensed with.

Physics in Relation to Engineering.—Physics has been placed after mathematics, as many physical problems are determined by mathematics; but in several respects physics, with its very wide scope in its relation to the various properties of matter, is of equal importance to engineers, for there are few problems in engineering in which no part is borne by physical considerations.

The surveyor avails himself of physics when heights are measured by the barometer, or by the temperature at which water boils; and the spirit-level is a physical instrument adapted by the surveyor for levelling across land. Evaporation, condensation, and latent heat are of great importance in regard to the efficiency of steam-engines; and the expansive force of the gases generated or exploded, the diminution of friction, and the retention of the heat developed are essential elements in the economical working of heat-engines. Allowance for expansion by heat and contraction by cold has to be made in all large structures; and deflections due to changes in temperature have to be taken into account. The temperature, also, which decreases with the elevation above the sea-level, and the distance from the equator, limits the height to which railways can be carried without danger of blocking by snow; whilst the temperature, by increasing about 1° F. with every 60 feet below the surface of the earth, limits the depth at which tunnels can be driven under high mountain ranges. Congelation of the soil is employed, as will be explained by M. Gobert, in excavations through water-bearing strata.

Compressed air is used by engineers for excluding the water from subaqueous foundations, so that excavations can be made and foundations laid, at considerable depths below the water-level, with the same certainty as on dry land. The compression of air, and its subsequent absorption of heat on being liberated and expanding in a chamber, are employed for refrigerating the chambers in which meat and other perishable supplies are preserved. Compressed air is employed for working the boring machinery in driving long tunnels through rock, and provides, at the same time, means of ventilation; and it also serves to convey parcels along pneumatic underground tubes. Moreover, the compressed-air and vacuum brakes are the most efficient systems of automatic and continuous brakes, which have done so much to promote safety in railway travelling, and in reducing the loss of time in the pulling up of frequently stopping trains. The production of a more perfect vacuum than can be produced by the ordinary air-pump, might have been supposed to be merely an interesting physical result (*Journal* of the Chemical Society, June 1864); but, in fact, the preservation of the heated filament of carbon in the incandescent electric light has been rendered possible only by the far more perfect vacuum obtained by the Sprengel vacuum-pump, by which the air is exhausted down to so low a pressure as a two-hundred millionth of an atmosphere.

The illuminating power of different sources of light is of great importance in determining the distance at which the concentrated rays from a lighthouse can be rendered visible, as well as in relation to the lighting of streets and houses; and the refrangibility of the rays emitted, or the nature of their spectrum, should not be disregarded, as upon this depends the power of a light to penetrate mist and fog, which cut off the rays at the violet end of the spectrum, and have comparatively little influence on the least refrangible red rays (*Proceedings* Inst. C.E., vol. lvii. pp. 145–148). The effect also of the colouring of lights on their visibility is of interest in determining the shades of colour to be used for signals and ship-lights, and also the relative power of the lights required for different colours to secure equal illuminating power. Distinctions of colour are essential in these cases; but for distinguishing lighthouses, the use of coloured glasses has been abandoned, on account of their impairing the light emitted; and the desired indication has been effected by varying the number and duration of the flashes and eclipses in each lighthouse. The detection of colour-blindness is of interest to engineers, as this physical infirmity incapacitates men from acting as engine-drivers, signalmen, or navigating seamen. The use of compressed oil-gas enables buoys and beacons to give a warning or guiding light for about three months without requiring attention; and the electric light has accelerated the passage through the Suez Canal from 30½ hours to 20 hours, and has greatly increased the capacity of the canal for traffic by enabling navigation to be carried on at night. The electric light also affords an excellent, safe, and cool light in the confined cabins on board ship, in the headings of long tunnels, and in the working-chambers filled with compressed air used for sinking subaqueous foundations.

Acoustics might seem to have little relation to engineering; but the soundness of the wheels of a train are tested by the noise they give when struck with a hammer; warning notes are emitted by railway and steamship whistles, the foghorn on board ship, and the whistling and bell-buoys employed for marking shoals or the navigable channel; whilst the striking of bells, the blast of steam sirens, and the explosion of compressed gun-cotton cartridges and rockets indicate the position of lighthouses in foggy weather. The most powerful sounds that can be produced by the help of steam appear to have a very limited range as compared with light; for, under ordinary conditions, the most powerful siren ceases to be audible at a distance of six or seven miles; whilst the transmission of sound is very much affected by the wind and the condition of the atmosphere. It seems possible that loud detonations at short intervals may be more readily heard than the continuous blast of a steam trumpet.

Electrical engineering is very intimately connected with physics, for it really is the application of electricity to industrial purposes. The very close relation between electricity and magnetism, discovered by Oersted in 1820, and further established by the remarkable researches of Faraday, has led to the present system of generating electricity by the relative movement of coiled conductors and electro-magnets, in dynamo-electric machines worked by a steam-engine or other motive power. The electrical current thus generated can be transmitted to a distance with little loss of energy; and it can either be used directly for lighting by arc or incandescent lamps, or be reconverted into mechanical power by the intervention of another dynamo. Electricity is also employed for the simultaneous firing of a series of mines, at a safe distance from the site of the explosion.

The convertibility of heat and energy, indicated by Mayer, forms the basis of thermodynamics; and the mechanical equivalent of heat, a physical problem of the highest interest, determined by Joule in 1843, furnishes a measure of the amount of work that can be possibly obtained by a given expenditure of heat in heat-engines.

The above summary indicates how the discoveries of physics are applied to many branches of engineering; and a knowledge of the laws of physics, and of the results of physical researches, appears, therefore, essential for the successful prosecution of engineering works. The very intimate relation of mechanical science to mathematics and physics, and the indebtedness of engineers to men of science outside the ranks of their own profession, are, indeed, evidenced by the roll of the Presidents of Section G, containing the names of Dr. Robinson, Mr. Babbage, Prof. Willis, Prof. Walker, and Lord Rosse.

Chemistry in Relation to Engineering.—Gas-making is in reality a chemical operation on a large scale, consisting in the destructive distillation of coal, the purification and collection of the resulting carburetted hydrogen, and the separation and utilisation of the residual products. Chemistry, accordingly, holds a very important place in the requirements of the gas engineer.

The manufacture of iron, steel, and other metals, and the formation of alloys, are essentially chemical operations; and the Bessemer and Gilchrist processes, by which steel is produced in large quantities directly from cast iron, by eliminating a portion of the carbon contained in it, and also the injurious impurities, silicon and phosphorus, in place of the former costly and circuitous method of removing the carbon from cast iron to form wrought iron, and then combining a smaller proportion of carbon with the wrought iron to form steel, are based on definite chemical changes, and necessitated chemical knowledge for their development.

Chemical analysis is needed for determining the purity of a supply of water, or the nature and extent of its contamination; and Dr. Clarke's process for softening hard water, by the addition of lime water, depends upon a chemical reaction. The methods, also, of purifying water by filtration, shaking up with scrap iron, and aëration, are chemical operations on an extensive scale; and their efficiency has to be ascertained by chemical tests.

Cements and mortars depend for their strength and tenacity, when mixed with water, upon their chemical composition and the chemical changes which occur. The value of Portland cement requires to be tested quite as much by a chemical analysis of its component parts as by the direct tensile strength of its briquettes; for an apparently strong cement may contain the elements of its own disruption, in a moderate proportion of magnesia or in an excess of lime. The chemical change which has been found to occur in the Portland cement of very porous concrete exposed to the percolation of sea-water under considerable pressure, by the substitution of the magnesia in sea-water for the lime in the cement, if proved to take place even slowly under ordinary circumstances, would render the duration of the numerous sea works constructed with Portland cement very precarious, and necessitate the abandonment of this very convenient material by the maritime engineer.

Explosives, which have rendered such important services to engineers in the construction of works through rock and the blasting of reefs under water, as well as for purposes of attack and defence, form an important branch of chemical research. The uses of gun-cotton as an explosive agent, though not for guns, have been greatly extended by the investigations of Sir Frederick Abel, and by the discovery that it can be detonated, when wet and unconfined, by fulminate of mercury; whilst smokeless powder, a more recent chemical discovery, seems likely, by its application to firearms, to produce important modifications in the conditions of warfare. The progress achieved by chemists in other forms of explosives has been marked by their successive introduction for blasting in large engineering works. Thus the removal of the rock in driving the Mont Cenis tunnel, in 1857–71, was effected by ordinary blasting powder; whilst the excavation of the longer St. Gothard tunnel, in 1872–82, was accomplished by the more efficient explosive dynamite (*Proceedings Inst. C.E.*, vol. xcv. p. 266). Moreover, the first great blast for removing the portion of Hallett's Reef which obstructed the approach to New York Harbour, was effected mainly by dynamite, together with vulcan powder and rendrock, in 1876; whereas the far larger Flood Rock, in mid-channel, was shattered in 1885 by rackarock, a mixture of potassium chlorate and nitrobenzol, and a much cheaper and a more efficient explosive under water than dynamite (*Ibid.*, vol. xcv. pp. 267–270). Rackarock is one of the series of safety explosives first investigated by Dr. Sprengel in 1870, which, consisting of a solid and a liquid, is safely and easily mixed for use; and these materials, being harmless previously to their admixture, can be stored in large quantities without risk (*Journal of the Chemical Society*, August 1873). The cost also of this large blast was greatly reduced by the sympathetic explosion of the bulk of the cartridges by the detonation of a series of primary exploders, placed at intervals along the galleries and fired simultaneously by electricity from the shore.

The utilisation of sewage belongs to agricultural chemistry; and the deodorisation of sewage, and its conversion into a commercial manure, are chemical processes. The disposal of sewage by irrigation is a branch of agriculture; and the innocuous character of the effluent fluid, discharged into the nearest stream or river, has to be ascertained by chemical analysis. Chemists have the opportunity of benefiting the community, and at the same time acquiring a fortune, by discovering an economical and efficient process for converting sewage on a large scale into a profitable saleable manure, so that inland towns may not have to dispose of their sewage at a loss, and that towns situated on tidal estuaries or the sea-coast may no longer discharge their sewage into the sea, but distribute it productively on the land.

The purifying of the atmosphere from smoke, rendered increasingly expedient by the growth of population, and the prevention of the dense fogs caused by it, by some practical method for more thoroughly consuming the solid particles of the fuel, still await the combined efforts of chemists and engineers.

Geology in Relation to Engineering.—A knowledge of the superficial strata of the earth is important for all underground works, and essential for the success of mining operations. Geology is indispensable in directing the search for coal, iron ore, and the various metals; and the existence of faults or other disturbances may greatly modify the conditions. The value of geology to the engineer is not, however, confined to the extraction of minerals, for it extends, more or less, to all works going below the surface.

The water-supply of a district, in the absence of a suitable river or stream, is dependent on the configuration and geology of the district; and the spread of London before the extension of waterworks, as pointed out by Prof. Prestwich, had to be confined to the limits of the gravel subsoil, in which shallow wells gave access to the water arrested by the stratum of underlying London clay. The sinking also of deep wells for a supply of water, and the depth to which they should be carried, are determined by the nature of the formation, the position of faults, and the situation of the outcrop of the water-bearing stratum. A geological examination, moreover, of a site proposed for a reservoir, to be formed by a reservoir dam across a valley, has to be made to ascertain the absence of fissures and the soundness of the foundation for the dam.

In the driving of long tunnels, the nature and hardness of the strata and their dip, the prospects of slips, and the possibility of the influx of large volumes of water, are geological considerations which affect the designs and the estimates of cost. The excavations also of large railway cuttings and ship canals are considerably affected, both as regards their side slopes and cost, by the nature and condition of the strata traversed.

Meteorology in Relation to Engineering.—The maximum pressure that may be exerted by the wind has to be allowed for in calculating the strains which roofs, bridges, and other structures are liable to have to bear in exposed situations; and con-

tinuous records of anemometers for long periods are required for determining this pressure. The force of the wind also, and the direction, duration, and period of occurrence of severe gales, are important to the maritime engineer for estimating the effect of the waves in any special locality, for determining the quarter from which shelter is needed, and for ascertaining the seasons most suitable for the execution of harbour works, the repair of damages, and the carrying out of foundations of lighthouses and beacons on exposed rocks. The harbour engineer must, indeed, of necessity be somewhat of a meteorologist, for the changes in the wind and weather, the oscillations of the barometer, and the signs of an approaching storm are indications to him of approaching danger to his works, which he has to guard against; for the sea is an insidious enemy which soon discovers any weak spot, and may in a few hours destroy the work of months.

Continuous records of rainfall, as collected regularly by Mr. Symons from numerous stations in the United Kingdom, are extremely valuable to engineers for calculating the probable average yield of water from a given catchment area, the greatest and least discharges of a river or stream, the size of drainage channel needed to secure a low-lying area from floods, and the amount of water available for storage or irrigation in a hot, arid district. The loss of water by evaporation at different periods of the year, and under different conditions of soil and climate, the effect of percolation in reducing evaporation, and the influence of forests and vegetation in increasing the available rainfall, while equalising the flow of streams, are subjects of equal interest to hydraulic engineers and meteorologists.

Countries periodically visited by hurricanes, cyclones, or earthquakes, necessitate special precautions, and special designs for structures; and every additional information as to the force and extent of these visitations of nature is of value in enabling engineers to provide more effectually against their ravages.

Benefits conferred by Engineers upon Pure Science.—Engineering is generally concerned in the application of the researches of science for the benefit of mankind, and not in the extension of the domain of pure science, which necessitates greater concentration of attention and study than the engineer in practice is able to devote to it. Engineers, however, though never able to repay the ever-increasing debt of gratitude which they owe to past and present investigators of science, except in rendering these abstract researches of practical utility, have, nevertheless, been able incidentally to promote the progress of science. Thus mechanical science, by the construction of calculating machines, the planimeter, integrating machines, the tide-predictor and tidal harmonic analyser of Lord Kelvin, the self-registering tide-gauge, and various other instruments, has lightened the labours of mathematicians; whilst excavations for works, and borings have assisted the investigations of geologists. The mechanical genius of Lord Rosse led mainly to the success of the gigantic telescope, which has revealed so many secrets of the heavens; and the rapidity of locomotion, due to the labours of engineers, has greatly facilitated astronomical observations and physical discoveries, besides promoting the concourse of scientific men and the diffusion of knowledge. Electrical engineering, moreover, is so closely allied to electrical physics that the development of the one necessarily promotes the progress of the other. The observations also conducted by hydraulic and maritime engineers in the course of their practice aid in extending the statistics upon which the science of meteorology is based.

Engineering as an Experimental Science.—Engineering, so far as it is based on mathematics, is an exact science, and the strains due to given loads on a structure can be accurately determined; but the strength of the materials employed has to be ascertained before any structure can be properly designed. Accordingly, the resistance of materials to tension, compression, and flexure, has to be tested, and their limit of elasticity and breaking weight determined. Thus, previously to the construction, by Robert Stephenson, of the Britannia Tubular Bridge, the first wrought-iron girder bridge of large span erected, numerous experiments on various forms of wrought iron were carried out by that eminent mathematician and mechanician Eaton Hodgkinson, who had previously indicated the proper theoretical form for cast-iron girders, and to whom the success of the bridge across the Menai Straits was in great measure due ("The Britannia and Conway Tubular Bridges," Edwin Clark, vol. i. p. 83). Besides the numerous tests always now made of the materials employed during the progress of any large engineering work, railway bridges are also subjected to severe test loads before being opened for public traffic, by which the safety of the structures and their rigidity, as measured by the amount of deflection, are ascertained, serving as a guide for subsequent designs.

Numberless experiments have been made on the flow of water in open channels, over weirs, through orifices, and along pipes; and the influences of the nature of the bed, the slope, depth, and size of channel, have been investigated by various hydraulicians. Mr. Thomas Stevenson measured the force of waves at some places on the Scotch coast ("The Design and Construction of Harbours," Thomas Stevenson, 3rd ed. pp. 52-56); Prof. Osborne Reynolds has examined the laws of tidal flow in a model of the inner estuary of the Mersey, and in specially shaped experimental models ("British Association Reports" for 1889, 1890, and 1891); and I have found it possible, in small working models of the Mersey and Seine, not merely to reproduce the configuration of the bed of the estuary out to sea, but also to observe the effects of different forms of training works in modifying sandy estuaries.[1] Mr. William Froude, after his retirement from active practice, devoted his abilities to experiments on the motion and resistance of ships in water, which have proved of inestimable value to the naval architect, and which formed the subject of his presidential address to this Section in 1875.

Electrical engineering is specially adapted for experimental investigation; and, in this branch, theory and practice are so closely allied that some of the most eminent exponents of the theory of the subject, such as Lord Kelvin and Dr. Hopkinson, have developed their theories into practical results. In most other branches, the investigator is generally distinct from the engineer in large practice; but it may be safely said that an able investigator and generaliser in engineering science, as, for instance, the late Prof. Rankine, accomplishes work of more value to the profession at large than the practical engineer, who, in the world's estimation, appears the more successful man.

Every branch of engineering science is more or less capable of being advanced by experimental investigations; and when it is borne in mind that the force of waves, the ebb and flow of tides in rivers, the influences of training works in estuaries, and the motion of ships at sea have been subjected to experimental research, it appears impossible to assign a limit to the range of experiments as a means of extending engineering knowledge. Problems of considerable interest, which can only be solved by experiments or by comprehensive generalisations from a number of examples, must frequently present themselves to engineers in the course of their practice, as they have to myself; and engineers would render a great service to the profession if they would follow up the lines of investigation thus suggested to them, in the true spirit of scientific inquiry.

Failures of Works due to Neglect of Scientific Considerations.—Before the amount and distribution of the stresses in structures were thoroughly understood, a disposition was naturally evinced to err on the side of excessive strength; and the materials in the various parts of the structure were not suitably proportioned to the load to be borne, resulting in a waste of materials and too great an expenditure on the works. Thus some of the early high masonry reservoir dams in Spain exhibit an excessive thickness towards the top, imposing an unnecessary load on the foundations; and in many of the earlier iron girder bridges more material was employed than was required for stability, and it was not properly distributed. Boldness engendered by increased experience, and dictated by motives of economy, has tended to make the engineers of the present day pursue an opposite course; and, under these circumstances, the correct calculation of the strains, the exact strength of the materials, and a strict appreciation of the physical laws affecting the designs become of the utmost importance.

The failures of many bridges may be explained by errors in design, defects in construction, or by economy carried beyond the limits of safety in pushing forward railways in undeveloped countries; but other failures are attributable to a disregard or underestimation of the influence of physical causes. Thus the Tay Bridge disaster, in 1879, was due to underestimating the amount and effect of the wind-pressure in an exposed situation, where it acted with a considerable leverage, owing to the height of the bridge, and was inadequately provided against by the

[1] *Proceedings* of the Royal Society, vol. xlv. pp. 504-524, and plates 2-4; vol. xlvii. p. 142; and "Amélioration de la Partie Maritime des Fleuves, y compris leurs Embouchures," L. F. Vernon-Harcourt, Paris Inland Navigation Congress, 1892, pp. 27-29, and 32, 33, and plate 3.

small transverse width of the piers in proportion to their height, which were further weakened by bad workmanship in the bracing of their columns. The bursting of the Bouzey masonry dam in France this year must be attributed to an inadequate thickness at part of the cross-section, producing a tensional strain on the inner face with the reservoir full, aided by the instability resulting from a fissured foundation. The overthrow of the outer arms of the Madras breakwaters, during a cyclone in 1881, may be traced to an inadequate estimate of the force of the waves in a storm, in deep water, and with a great fetch across the Indian Ocean, beating against the portions of the breakwaters directly facing their course; for these outer portions, running nearly parallel to the coast-line, were not made any stronger than the inner portions placed at right angles to the shore and the direction of the waves, and situated for the most part in shallower water. The erosion of the bed of the Ganges Canal on the first admission of the water, necessitating the erection of weirs at intervals to check the current, resulted from an error in the calculated discharge of the channel with the given inclination, and the consequent undue velocity of the stream, producing scour. The failure of the jetty works at the outlet of the Rhone to effect any permanent deepening of the channel over the bar, was due to the unsuitable direction given to the outlet channel in view of the physical conditions of the site, and the concentration of all the discharge, and consequently all the alluvium carried down, into a single mouth, whereby the rate of deposit in front of this outlet has been considerably increased. The excessive cost, and consequent stoppage, of the Panama Canal works, though due to a variety of causes, must be partly attributed to want of due consideration of the strata to be excavated; for a cutting of 300 feet in depth, which may be possible in rock, becomes impracticable when a considerable portion has to be executed in very treacherous clay.

Occasionally failures of works may be attributed to exceptional causes or peculiarly unfavourable conditions; but in most cases, as in the instances given above, they are the result of errors or deficiencies in design, which might have been avoided by a more correct appreciation of the physical conditions involved.

Scientific Training of Engineers.—In most professions, preliminary training in those branches of knowledge calculated to fit a student for the exercise of his profession is considered indispensably necessary; and examinations to test the proficiency of candidates have to be passed as a necessary qualification for admission into the Army, Navy, Church, Civil Service, and both branches of the law. Special care is taken in securing an adequate preliminary training in the case of persons to whom the health of individuals is to be entrusted, not merely by experience in hospitals, but also by examinations in those branches of science and practice relating to medicine and surgery, before the medical student can become a qualified practitioner. If so much caution is exercised in protecting individuals from being attended by doctors possessing insufficient knowledge of the rudiments of their profession, how much more necessary should it be to ensure that engineers are similarly qualified, to whom the safety and well-being of the community, as well as large responsibilities in regard to expenditure, are liable to be entrusted! The duty of the engineer is to apply the resources of nature and science to the material benefit and progress of mankind; and it, therefore, seems irrational that no guarantee should be provided that persons, before becoming engineers, should acquire some knowledge of natural laws, and of the principles of those sciences which form the basis of engineering. The Institution of Civil Engineers has, indeed, of recent years required some evidence of young men having received a good education before their admission into the student class; but some of the examinations accepted as sufficient for studentship, such as a degree in any British university, afford no certainty in themselves that the persons who have passed them possess any of the qualifications requisite for an engineer; and it is quite unnecessary to become a student of the Institution in order to become an engineer. The Council of the Institution has no doubt been hitherto deterred from proposing the establishment of an examination in mathematics and natural science, as a necessary preliminary to becoming an engineer, by the remembrance that some of the most distinguished engineers of early days in this country were self-taught men; but since those days engineering and the sciences upon which it is based have made marvellous advances; and in view of these developments, and the excellent theoretical training given to foreign engineers, it is essential that British engineers, if they desire to retain their present position in the world, should arrange that the recruits to their profession may be amply qualified at their entrance in theoretical knowledge, in order to preserve the standard attained, and to be in a position to achieve further progress. No amount of preliminary training will, indeed, necessarily secure the success of an engineer, any more than the greatest proficiency would be certain to lead the medical student to renown as a physician or surgeon; but other conditions being equal, it will greatly promote his prospects of advancement in his profession, and his utility to his colleagues and the public. The engineers of the past achieved great results in the then early dawn of engineering knowledge, by sound common sense, a ready grasp of first principles and of the essential points of a question, capacity for acquiring knowledge, power of managing men and impressing them with confidence, and shrewdness in selecting competent assistants. These same qualities are still needed for success in the present day, coupled with an opportunity of exhibiting them; but far more knowledge of mathematics and other sciences is required now, owing to the enormous advances effected, if the progress of engineering science is to be maintained. Even though in some branches, engineers in large practice may not have the time, or retain the requisite facility, for solving intricate mathematical problems, they should be able readily to comprehend the full bearing of the principles presented, and to understand the nature of the solutions put before them, which nothing but the scientific faculty implanted by early training in mathematics and physics can adequately secure.

A qualifying examination for engineers would usefully stop persons at the outset from entering the profession, who failed to evince the possession of the requisite preliminary knowledge: it would indicate, by the subjects selected, the kind of training best calculated to fit a person to become a useful engineer; and it would protect the public, as far as practicable, from the injuries or waste of money that might result from the mistakes of ill-qualified engineers.

Specialising in Engineering.—Some branches of engineering have for a long time been kept distinct from others, such as the construction of steam-engines, locomotives, and marine engines, ship-building, heavy ordnance, hydraulic machinery, and other purely mechanical works, one or more of which have been treated as specialities by certain firms, and also gas lighting, and, more recently, electric lighting. In the department, however, of civil engineering in its narrower signification, as distinguished from mechanical engineering, engineers of former times were regarded as equally qualified to undertake any of the branches of public works; and the same engineer might be entrusted with the execution of roads, railways, canals, harbours, docks, sewerage works, and waterworks; while even steamships were not excluded from the category in Brunel's practice. The engineer of to-day, indeed, would be lacking that important factor for success, common sense, if he declined to execute any class of works which he might be asked to undertake; and a variety of works is very useful to the engineer in enlarging his views and experience, as well as in extending the range of his practice. The tendency, however, now in engineering, as in medicine, is for the engineer's practice to be confined to the special branch in which he had had most experience; a result which cannot fail to be beneficial to the public, and calculated to promote the progress of each branch. The powers of the human mind are too limited, and life is too short, for engineers to be able to acquire, in the present day, equal proficiency in the theory and practice of the several branches of engineering science, with their ever-widening scope and development; and, as in the domain of abstract science, general progress will be best achieved in engineering science by the concentration of the energies of engineers in the advancement of their special line of practice.

Value of Congresses on Special Branches of Engineering.—The scope of engineering science is extending so fast that it is impossible for the Institution of Civil Engineers, which, as the parent society, embraces every branch within its range of subjects, to give more than a very limited time for the consideration and discussion of papers relating to the non-mechanical branches of the profession comprised in public works. Mechanical, electrical, and gas engineers have special societies of their own for advancing their knowledge and publishing their views and experience, while sharing equally with the other branches in the benefits of the older Institution.

Congresses accordingly afford a valuable opportunity for railway, hydraulic, and sanitary engineers of expressing their views, and enlarging their experience by consultation and discussion with engineers of various countries. My experience of the six maritime, inland navigation, and waterworks international congresses I have attended in England and abroad, has convinced me of the very great value of such meetings in collecting information, comparing views, and obtaining some knowledge of foreign works and methods; whilst the acquaintances formed with some of the most celebrated foreign engineers, afford opportunities of gaining further information about works abroad, and deriving experience from their progress and results.

Engineering Literature.—Lawyers have been defined as persons who do not possess a knowledge of law, but who know where to find the law which they may require. It may be hoped that a similar definition is not applicable to engineers; but with the rapid increase of engineering literature, it is most desirable that engineers should be able readily to refer to the information on any special subject, or descriptions of any executed works, which may have been published. Much valuable matter, however, is buried in the proceedings of engineering and scientific societies, and in various publications; and often a considerable amount of time is expended in fruitless search. This great waste of time and energy, and the loss of available information involved, led me a few years ago to suggest that a catalogue of engineering literature ought to be made, arranging the lists of publications relating to the several branches under separate headings. There is a possibility that this arduous and costly task may be partially accomplished in separate volumes; and, at any rate, the first step has been effected by the publication, under the auspices of the Paris Inland Navigation Congress of 1892, of a catalogue of the publications on inland navigation. A start has also been made in France, Italy, and England, towards the preparation of a similar catalogue on maritime works, which it may be hoped means one day will be found to publish on the meeting of some future congress. Engineers who have searched, even in the best libraries, for the published information on any special subject, will appreciate what a great boon an engineering subject catalogue would be to the profession, and indirectly to the public at large.

The occasional publication of comprehensive books on special branches of engineering, and concise papers on special subjects, by competent authorities, are extremely valuable in advancing and systematising engineering knowledge; but the time and trouble involved in the preparation of such publications must, like the organising of congresses, be regarded as a duty performed in the interests of the profession and science, and not as affording a prospect of any pecuniary benefit.

Concluding Remarks.—In this address I have endeavoured, though very imperfectly, to indicate how engineering consists in the application of natural laws and the researches of science for the benefit and advancement of mankind, and to point out that increased knowledge will be constantly needed to keep pace with, and to carry on, the progress that has been made. The great advantages provided by engineering works in facilitating communications and intercourse, and consequently the diffusion of knowledge, in increasing trade, in extending civilisation to remote regions, in multiplying the comforts of life, and affording enlarged possibilities of enjoyment and change of scene, may be regarded as amply acknowledged; but the more gradual and less obvious, though not less important, benefits effected by engineering works are not so fully realised.

A comparison of engineering with the other chief branch of applied science, medicine, exhibits some similarities and differences. In both professions, the discoveries of science are utilised on behalf of mankind; but whilst physicians devote themselves mainly to individuals, engineers are concerned in promoting the well-being of the community at large. Persons reluctantly consult doctors when they are attacked by disease, or incapacitated by an accident; but they eagerly resort for enjoyment to railways, steamships, mountain tramways, piers, great wheels, and Eiffel towers; and they frequently avail themselves of the means of cheap and easy locomotion to complete their restoration to health by change of air and climate. Physicians try to cure people when they are ill: whereas engineers endeavour, by good water-supply and efficient drainage, to maintain them in health; and in this respect, the evident results of medical skill are far more readily realised than the invisible, though more widespread, preventive benefits of engineering works. Statistics alone can reveal the silent operations of sanitary work; and probably no better evidence could be given of the inestimable value of good water and proper drainage on the health of the population of large towns, when aided by the progress of medical science, than the case of London, where, towards the close of the last century, the death-rate exceeded the birth-rate, and the numbers were only kept up by constant immigrations; whereas now, in spite of the vast increase of the population and the progressive absorption of the adjacent country into the ever-widening circle of houses, the number of births exceed the deaths by nearly nine hundred a week.

In engineering, as in pure science, it is impossible to stand still; and engineers require to be ever learning, ever seeking, to appreciate more fully the laws of nature and the revelations of science, ever endeavouring to perfect their methods by the light of fresh discoveries, and ever striving to make past experience and a wider knowledge stepping-stones to greater achievements. Engineers have a noble vocation, and should aim at attaining a lofty ideal; and, in the spirit of the celebrated scientific discoverers of the past, such as Galileo, Newton, Laplace, Cavendish, Lyell, and Faraday, should regard their profession, not so much as an opportunity of gaining a pecuniary reward, as a means of advancing knowledge, health, and prosperity.

The remarkable triumphs of engineering have been due to the patient and long-continued researches of successive generations of mathematicians, physicists, and other scientific investigators; and it is by the utilisation of these stores of knowledge and experience that engineers have acquired renown. A higher tribute of gratitude should perhaps be paid to the noble band of scientific investigators who, in pursuit of knowledge for its own sake, have rendered possible the achievements of engineering, than to those who have made use of their discoveries for the attainment of practical benefits; but they must both be regarded as co-workers in the promotion of the welfare of mankind. The advancement of science develops the intellectual faculties of nations, and enlarges their range; whilst the resulting progress in engineering increases their material comforts and prosperity. If men of science, by closer intercourse with engineers, could realise more fully the practical capabilities of their researches, and engineers, by a more complete scientific training, could gain a clearer insight into the scientific aspect of their profession, both might be able to co-operate more thoroughly in developing the resources of nature, and in furthering the intellectual and material progress of the human race.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SECOND SPRINGFIELD MEETING.

THE forty-fourth meeting of the American Association for the Advancement of Science was held at Springfield, Mass., August 29 to September 4, being the second meeting held at that city; the first was in 1859.

In the early history of the Association frequent meetings were held in New England, but fifteen years have passed since the last preceding New England meeting, held at Boston. The social and intellectual life of all New England cities ranks high, and the Association found a most appreciative and hospitable community.

A copy of the address of the retiring President, Dr. Daniel G. Brinton, on "The Aims of Anthropology," has already been sent to NATURE. It was a matter for regret that the author was unable to attend and read it personally.

The vice-presidential addresses were not quite so many as usual, owing to the resignation of Profs. Holden and Jordan as presidents of the Sections of Astronomy and Zoology, respectively, because of the change in place of meeting from California, where they reside, and where it was intended to meet if the trans-continental railroads had reduced fares sufficiently. The addresses delivered were by W. L. Stevens, on "Recent Progress in Optics"; William McMurtrie, on "The Relation of the Industries to the Advancement of Chemical Science"; William Kent, on "The Relation of Engineering to Optics"; J. Hotchkiss, on "The Geological Survey of Virginia, 1835–1841: its History and Influence in the Advancement of Geologic Science"; J. C. Arthur, on "The Development of Vegetable Physiology"; F. H. Cushing, on "The Arrow"; and B. E. Fernow, on "The Providential Function of Government n Relation to Natural Resources."

One of the first and most important matters of business presented was in reference to the proposed meeting of the British Association in Toronto in 1897. The writer offered a resolution cordially inviting the Association, in case they decide to accept the invitations already sent them from Toronto to hold the meeting there, to attend our meeting also as our guests, and requesting them to send early notice of the time of meeting to the Permanent Secretary of our Association, that ample time may be had to make suitable arrangements, and to renew the delightful memories of the Philadelphia meeting in 1884. This was referred to the Permanent Secretary with power.

Should the Association come to America as proposed, it seems probable that the long-deferred San Francisco meeting will then be held, as it is believed that many visitors will desire to cross the continent by the Canadian Pacific Railroad, which was incomplete at the time of the Montreal meeting in 1884; but many who attended that meeting went as far west as the road would then take them. As Sir Wm. C. Van Horne, President of that road, is a member of the British Association, and has been a member of ours, his influence is relied on to secure favourable rates of transportation. Still another factor is that the Christian Endeavour Societies expect to meet at San Francisco in 1897, and as they are a mighty army—70,000 attended the Boston meeting this summer—the railroads usually offer exceptional rates to secure their patronage, and the Associations can share in the benefit of the reduction.

Of the 207 papers read before the several Sections, many might be mentioned. The subject of colour and colour standards, on which Mr. Pillsbury had an article in a recent number of NATURE, was presented by him and others, and resolutions were passed looking toward the establishment of a colour standard. E. R. von Nardroff exhibited and described a new apparatus for studying colour phenomena. Colour photography was discussed and photographs exhibited by F. E. Ives.

A process for photographing the vocal cords in action has been discovered by F. S. Muckey and Wm. Hallock, and it is found that the pitch of a note is raised by rotating the arytenoid cartilages without increasing the tension of the cords, just as a violinist makes high notes by shortening the string with his finger. Voice analysis also has been studied by Messrs. Hallock and Muckey, by an ingenious system of resonators for the fundamental and seven overtones, covering three octaves from the fundamental C. These resonators are so arranged that the vibration of each causes the flickering of a tiny gas jet, and by observing these it can be seen which of the overtones are sounding, and by drawing straight or wavy lines to correspond with each of these, a picture of the tone can be made. This will enable a singer to see every tone in his voice, and learn wherein he needs to correct it.

The Weather Bureau of the United States supplied experts to fill up an afternoon in a joint meeting of four Sections. Willis L. Moore, the new chief of the bureau, spoke of the work in hand and that contemplated. An elaborate scheme of observation of upper strata of the air by kites and balloons and kite-balloons is to be carried out; and regular observations are to be made of "sensible temperature" by the wet bulb thermometer.

Frank N. Bigelow, in his paper on solar magnetic radiation and weather forecasts, made some very remarkable statements. The sun, he says, throws out curved lines of magnetic force. These are connected with sun-spots, and with storms on the earth. They have been studied by him so carefully that he fixes the time of the sun's axial revolution more accurately than ever before at 26·67928 days, with a probable error only in the last or possibly the two last figures. A surprising inference from his studies is that the earth has a crust 800 miles thick, and the sun has also a crust. Future investigation will supply data for a long forecast of seasonal weather conditions, years ahead. Cleveland Abbe followed with a paper on clouds and their nomenclature, and Alfred J. Henry with some very beautiful cloud photographs.

Electro-metallurgy has made rapid strides, and a paper on calcium carbide, by P. de Chalmot and J. T. Morehead, gave an account of the process used at their works in Spray, N.C., for cheap production of this compound by smelting together lime and coke in the electric furnace. This enables them to produce acetylene, the illuminating principle of gas, much cheaper than any other process.

A paper on the new process of making white-lead by electric action was read by R. P. Williams before the American Chemical Society, which met at Springfield two days earlier than the Association. Mr. Williams describes the process, which will work a revolution in this industry. Instead of acetate of lead, as in the old process, sodium nitrate is used together with sodium bicarbonate. A number of cells are filled with the solution, with plates of lead at one pole and of copper at the other. The current from a dynamo causes nitric acid to be liberated and to combine with the lead. A number of reactions occur, with the final production of white-lead in a very fine and uniform state and of superior colouring quality. The chemicals can be re-used indefinitely. As many as 500 pounds have already been made at one charge.

The Economic Section has always been one of great popular interest. The monetary question, monometallism or bimetallism, by J. W. Sylvester and Henry Farquhar; taxation in the United States, by Edward Atkinson; growth of great cities, by E. L. Corthell; manual training in horticulture, by W. R. Lazenby, were among the matters treated of. An effort was made to widen the scope of this Section by a change of name. Its name—Section of Economic Science and Statistics—was deemed peculiarly undesirable, and after much discussion of the respective merits of "sociology" and "social and economic science," the latter title was adopted as the name of Section I.

Buffalo was unanimously chosen as the next place of meeting, following the practice of the Association to meet at that city every tenth year, beginning with 1866, when 79 members there reorganised the Association after six years of suspended animation, during which no meeting had been held.

The time for meeting was much controverted. The Council recommended a change to Monday as the opening day, which met decided opposition, and on an informal vote 30 were opposed to it and only 27 favoured it; but opposition at length gave way, and the next meeting will begin on Monday, August 24, 1896, at Buffalo.

Officers elected were—President: Edward D. Cope, of Philadelphia. Vice-Presidents: A, Mathematics and Astronomy, William E. Story of Worcester; B, Physics, Carl Leo Mees of Terre Haute, Ind.; C, Chemistry, W. A. Noyes of Terre Haute, Ind.; D, Mechanical Science and Engineering, Frank O. Marvin of Lawrence, Kan.; E, Geology and Geography, B. K. Emerson of Amherst; F, Zoology, Theodore N. Gill of Washington; G, Botany, N. L. Britton of New York city; H, Anthropology, Alice C. Fletcher of Washington; I, Social Science, William R. Lazenby of Columbus, O. Permanent Secretary: F. W. Putnam of Cambridge. General Secretary: Charles R. Barnes of Madison, Wis. Secretary of the Council: Asaph Hall, Junr., of Ann Arbor, Mich. Secretaries of the Sections: A, Mathematics and Astronomy, Edwin B. Frost of Hanover, N.H.; B, Physics, Frank P. Whitman of Cleveland, O.; C, Chemistry, Frank P. Venable of Chapel Hill, N.C.; D, Mechanical Science and Engineering, John Galbraith of Toronto, Can.; E, Geology and Geography, A. C. Gill of Ithaca, N.Y.; F, Zoology, D. S. Kellicott of Columbus, O.; G, Botany, George F. Atkinson of Ithaca, N.Y.; H, Anthropology, John G. Bourke, United States Army; I, Social Science, R. T. Colburn of Elizabeth, N.J. Treasurer, R. S. Woodward of New York.

WM. H. HALE.

LETTERS TO THE EDITOR.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

August Meteors.—Red Spot on Jupiter.

As supplementary to my paper on the August meteors (NATURE, No. 1347, August 22) and to Prof. A. S. Herschel's interesting letter on the same subject (No. 1349, September 5), I may note that a further comparison of the recent observations has revealed two additional instances of doubly observed meteors.

On August 11, 10h. 59m., Prof. Herschel at Slough recorded a meteor equal in brightness to a first magnitude star and moving swiftly along a path of $22\frac{1}{2}^\circ$ from $264^\circ + 52^\circ$ to $252^\circ + 31^\circ$, or from the head of Draco into Hercules. The meteor left a long, thin, white streak for 2 secs., and the duration of flight was estimated as 1 sec. Mr. H. Corder, at Bridgwater, observed the same object, noting the time as 10h. 58m., and the apparent path as $23^\circ + 53\frac{1}{2}^\circ$ to $14^\circ + 50^\circ$ between Cassiopeia and Andromeda.

The meteor was evidently a Perseid, and had a radiant at $36° + 57°$. It was first seen when at a height of 95 miles above Oxford, and disappeared when 61 miles above Devizes. Its real length of path was 53 miles, and the earth point is indicated in the English Channel about 10 miles south of Lyme Regis, Dorsetshire.

On August 11, 11h. 43m., Prof. Herschel mapped a small bolide, rivalling Jupiter in brightness, and traversing with moderate speed a course of 15° from $229° + 59°$ to $225° + 44°$, or from near ι Draconis to the head of Boötes. Duration of flight 1·5 sec.; the nucleus was evenly bright all the way, and it left a streak for 3 secs. Mr. Corder registered the same meteor, and gives the time as 11h. 42m., magnitude equal to Jupiter, and path as $60° + 62\frac{1}{2}°$ to $70° + 64°$ in Camelopardus. This object was also a Perseid, the radiant being at $32° + 52°$ near the cluster at χ Persei. The meteor at its first appearance was 75 miles high above a point 5 miles N. of Stratford-on-Avon, and at its disappearance 52 miles high over a place 5 miles W.N.W. of Great Malvern. Its real length of path was 34 miles, and earth point 6 miles S.E. of Aberdare.

Red Spot on Jupiter.—When twilight became too strong for comet-seeking on the morning of August 25 last, I turned my 10-inch reflector on Jupiter and saw the red spot, indefinitely, near its central transit. The planet had only just risen above the tops of some houses in this locality, and the telescopic image was by no means good, but I estimated the transit of the spot occurred at 4h. 24m. A.M. (August 24, 16h. 24m.), or about 9·4m. after Mr. Marth's zero meridian, System II., so that the longitude of the spot was 5°·7. The shouldering of the great south equatorial belt, east of the spot, was very conspicuous, and afforded an excellent guide to the position of the latter. A few minutes after the transit of the red spot I noticed a large white spot on the north side of the north equatorial belt, passing the central meridian. A power of 312 was used in these observations.

W. F. DENNING.

Bristol, September 7.

Curious Optical Phenomenon.

THE following description of an optical phenomenon, and its probable explanation, may be of interest. It will be observed that a similar experience occurring to one not accustomed to making optical experiments would very probably have caused him to believe that he had seen a ghost. It is therefore of importance psychologically.

The facts observed were as follows:—At about 1 A.M., August 26, I went to my bedroom; to get to it I had to pass through a small room which I used as a study. On entering it, though it was dark, and I had no lamp, the small room seemed brightly illuminated, about as bright as an 8 c.p. lamp would make it, apparently. To one side of a window in the room I saw a man standing, whom I recognised to be myself. The whole impression was very vivid and clear.

So far nothing was observed beyond what is described in the ordinary ghost story. I was much occupied with the consideration of a problem at which I had been working, and did not at first grasp the full signification of what I saw. On turning my head, the figure disappeared, but on looking towards the window, through which a very faint line came, the image reappeared. I then noticed that it was apparently standing in a position occupied, as I knew, by a large table. On more close examination, without, however, moving from the spot where I was standing, I saw that it had changed, and that it did not appear to have features; then it appeared to be flat against the wall, and I finally recognised it as an after-image of a shadow. On my first seeing it, however, it did not have this appearance to me, and I had evidently mentally supplied the features as one often does to the face of a friend who is seen at a distance which is really too great to admit of actual recognition.

I then got the impression of having seen the shadow before, and on considering the matter a few seconds, remembered that it was just before I had started for my room. I had been working in another room, endeavouring to solve a physical problem for four or five hours, and for about half an hour, or possibly more, had been steadily looking at a lamp (a habit of mine when abstracted); I then got up, leaving the lamp lit, and went out on my way to my bed-room as mentioned above. On going out of the door my shadow was thrown by the lamp on the wall just to the right of the door. The passages were entirely dark, and it was not until I entered the room used as a study, that the faint light coming through the window and falling on the same spot of the retina that was previously occupied by the image of the dark doorway, stimulated the after-image.

I may say that my health was of the best, but that I had been smoking heavily for a few days previously, and the fact had begun to force itself upon me.

I would especially remark upon the apparent brightness of the apparition. I had never seen an after-image so bright. On going back to the room where the lamp was, I proved that the appearance of the shadow thrown as I went out of the room corresponded with that of the image seen, minus of course the features and colour, which had been supplied by the imagination.

In speaking of optical phenomena, I would say that an easy way of showing that the colours seen in the colour-top are due to lack of accommodation, is by taking a piece of red paper or cloth, and turning the top till the inner or outer line matches it exactly. Then, without moving or changing the speed of the top, place before the eye a convex glass. The colour on the top will disappear, but that of the cloth will of course remain. Similar experiments to those observed with the top can be observed by drawing dark lines on a piece of glass, and waving dark and white paper behind them.

R. A. F.

A Remarkable Flight of Birds.

THE forms of birds flying at a great height and crossing the solar disc, as described by Mr. Bray in your issue of August 29, have been rather frequently seen here during the spring and autumn months, and the writer has always attributed such flights to migrating birds on passage. They have usually been noticed while observing the image of the sun projected on a card screen from the eyepiece of a small equatorial telescope; occasionally, however, they have attracted attention at night also, crossing the disc of the moon, upon which their forms are very clearly defined, and with careful focussing (which is very nearly the same as for parallel rays) it has almost been possible to identify the species from the shape of the wings and manner of flight; birds of the swallow tribe, in particular, have been clearly distinguished, and others resembling the thrush, possibly redwings or fieldfares, have been noticed. The direction of flight, according to the writer's experience, is nearly always towards the south in August and September, and the reverse in April.

On August 31, a continuous watch was kept on the moon from 8.50 to 9.35 P.M., using a power of 80 diameters on a reflector of 10 feet focus. Only eight birds were seen, however, four of them slowly crossing from north to south, the other two from west to east (nearly). They were evidently very distant. An estimate of the change of focus required for the apparently nearest bird gave ·15 inch. This would imply a distance of 7900 feet from the telescope, and the moon's altitude being about 14° the vertical height of this bird would be $7900 \times \sin 14° = 1900$ feet (about). Some of the birds, judging from their apparent size, must have been two or three times more distant, and therefore higher in the same proportion.

It would be very interesting to obtain systematic observations of such flights of birds from various localities during the migrating seasons. Possessors of telescopes would find these observations a good exercise in that kind of patience or endurance which is so necessary in observing, for instance, a so-called meteor shower at its maximum!

The writer would be glad to receive notes on the subject from those of your readers who may care to watch for birds during the autumn. Estimates of the angle subtended by the spread wings would perhaps give the most reliable means of ascertaining the height of the birds, and their direction of flight can easily be obtained by reference to the diurnal motion of the sun or moon. It is hoped that by collecting data of this kind some new facts may be learned regarding the mysterious habits of our bird visitors.

J. EVERSHED.

Kenley, Surrey.

THE WOBURN EXPERIMENTAL FRUIT FARM.

ON June 12 last a small party of those interested in agriculture and horticulture, including Mr. Herbert Gardner, Sir John Thorold, Prof. Armstrong, Prof. Warington, Dr. Voelcker, Mr. Charles Howard, Mr.

Carruthers, Mr. George Murray, and others, visited Woburn to make the first formal inspection of an institution which, under the above somewhat unpretentious title, has been established by the joint action of the Duke of Bedford and Mr. Spencer Pickering, F.R.S., in order to supply what has hitherto been a great national want.

The object of this institution is to provide an experimental station where all matters connected with horticulture, and especially with the culture of hardy fruits, may be investigated both from the scientific and practical point of view.

The origin of such an enterprise is always a matter of some interest, and it becomes all the more so in after years, when, too often, the details of its conception and evolution are irretrievably lost. In the present instance we may trace the origin to an accident in a chemical laboratory. It was owing to such an accident some years ago that Mr. Pickering, whose work in physical chemistry is well known, was driven to seek health in a partial existence in the country. Not having the means, however, to procure this in the orthodox manner without abandoning his scientific work, he resorted to the somewhat unusual means of getting air and exercise by becoming an agricultural labourer at Rothamsted. From an agricultural labourer to a small farmer and landowner the steps were not so tedious as is generally the case, and for some few years past Mr. Pickering has turned his attention, after the manner of many landowners, to horticulture and practical fructiculture. To any one of a scientific turn of mind the unsatisfactory basis on which the culture of fruit depends cannot fail to be apparent. Its present condition is little better than that of horticulture some fifty years ago. It rests mainly on the hard-earned and often one-sided experience of practical men, gardeners, for the most part, or nurserymen.

But the pressure of business will rarely allow a nurseryman to indulge in anything approaching to systematic research, and even when he does obtain any important results, they are liable to be looked on askance, as being possibly tinctured by mercenary considerations. Moreover, even amongst the highest practical authorities there is hardly a single point in the cultivation of fruit on which unanimity of opinion prevails; indeed, on some of even the most elementary processes there seem to be as many opinions as there are so-called authorities.

The desirability of having some station where such matters might be patiently investigated, and from which results might issue free from any taint of commercial expediency, was evident to Mr. Pickering, and not having himself the capital or land necessary for such an undertaking, he applied for assistance to a former college friend, the Duke of Bedford. The Dukes of Bedford have during generations past identified themselves with the progress of agriculture and horticulture, the present holder of the title showing no tendency to be eclipsed by his predecessors in these matters. As was probable, such a scheme met with the hearty approval of the Duke, and the result was the establishment of the present institution, conducted jointly by himself and Mr. Pickering.

The fruit farm is on the Duke's land near Ridgmount Station, and almost adjoins the land which is given up to the use of the Royal Agricultural Society as an experimental agricultural station. About twenty acres have been devoted to the purpose, and of this some fifteen have already been planted.

Everything at present justifies the anticipation that this station will be conducted in the liberal and thorough-going manner which alone can produce results capable of commanding the confidence of horticulturists, and the energy with which the work has been commenced indicates that no time will be lost in obtaining trustworthy results. It is but twelve months since the field was bearing a crop of roots and weeds (especially the latter), yet in spite of the adverse season, the ground has been thoroughly cleaned, roads, hedges, and fences have been made, a house built on it, and over 500 experimental plots have been planted; also an extensive nursery has been planted, as well as collections of various ornamental and useful trees and shrubs. A fine crop of eighty different varieties of strawberries has been already gathered. With such work accomplished, it is scarcely necessary to say that an able manager is resident on the farm. The present manager, Mr. L. Castle, is a man whose experience and knowledge will command the confidence of practical horticulturists.

It is only possible here to indicate briefly the character of some of the experiments instituted. Besides strawberries—the investigation of which will embrace not only the respective merits of different varieties, but also the comparative values of the varieties at different ages, and the effects of certain manures on the crop—apples have been selected for the majority of the experiments already begun. Sixty different experiments are arranged to test different methods of planting, of root and branch treatment, and different manurial treatment, each experiment being made on eighteen trees, six of each of three varieties, all of the same age, and all raised on the same stock. These trees are all dwarf trees, and certain of the experiments are repeated with standard trees on the free-growing stock, and also with other dwarf trees of a fourth variety. Thirty-eight plots have been devoted to ascertaining the influence of different methods of training on the quantity and quality of the crop, and a collection of about 120 good varieties of apples has been made, each variety being grown on different stocks, and subjected in each case to different methods of treatment. This collection of apples is also so arranged that it may be utilised for the investigation of insecticides, without destroying the value of the results as regards the comparison of the different varieties. A smaller but interesting collection of apples of Scotch, Irish, and foreign origin has also been made. The numerous shelter hedges which have been planted are also of considerable interest, since, from an economical point of view, they also are experimental. They are composed of different varieties of nuts, plums, damsons, crabs, quince, medlars, and berberries.

Other experiments of greater scientific interest than the above are, we understand, either in progress or in contemplation; amongst these may be mentioned the influence of different stocks on the scion, and the great question of the effects of self- or cross-fertilisation. Such experiments, however, necessitate the lapse of a considerable amount of time before they can be said even to have been started, if they are to be started on a really satisfactory basis.

Those who are familiar with Mr. Pickering's chemical work will not fear that sufficient attention to minute details will be absent from the present undertaking. As instances of the thoroughness with which small questions are being examined, we may mention experiments on the relative merits of different arrangements of the same number of trees in a given area, and of the different direction in which the rows run as regards the points of the compass. Or, again, experiments on the influence of the nature, position, and inclination of the cut given in pruning a branch, and also the improvements which are being devised in methods of measuring the evaporating power of the air.

But it is very noteworthy that the strictly practical and economical aspects of horticulture will receive more attention than is usually the case at experimental stations. Six demonstration plots of a quarter of an acre each have been planted to illustrate how land may be most advantageously cropped by farmers, growers, and cottagers respectively. The initial cost of each of these plots is known, and an accurate account of the incoming and outgoing connected with each will be kept. In the nursery,

to which allusion has already been made, trees and bushes are being raised for distribution amongst the Duke's tenantry. We are pleased, however, to find that these practical steps for the promotion of fructiculture do not originate in any extravagant notions of the all-saving powers of fruit-growing to remedy the present agricultural distress. Much harm has been done in this country by the special pleading of those who are faddists on the subject, and who advocate their fad by holding up to view all the notable cases of success, and all the possible advantages to be gained, while they keep in the background all the difficulties and dangers, minimise the costs of planting, and hide the numerous cases of failure. No one can question the fact that fruit-growing in England is a profitable occupation when properly conducted under favourable conditions of soil, climate, and distance from market; nor can it be doubted that a certain proportion (perhaps 5 or 10 per cent.) of those who are now ordinary farmers could become fruit farmers with great advantage to themselves, and it must also be admitted that the distribution of some knowledge of fruit-growing over the country generally would render the thousands of orchards attached to homesteads a source of small, or often substantial, profit to the holders, instead of being, as they are at present, a mere waste of land and money; but to imagine that every farmer can become a fruit grower is as absurd as imagining that every farmer could become a horse breeder. Even if such a metamorphosis were possible it would be suicidal; yet it should be pointed out that the fruit market in England is an exceptionally expansible one, and that prices of hard fruits would probably be but little affected even if the supply were doubled; the rapidly increasing importation of apples, which has now reached 5,000,000 bushels a year, has had no effect whatever on the market price of the fruit. These might have been grown in England just as well as abroad, for with a proper selection of varieties England need never fear a competition with foreign-grown apples.

It is certainly a fallacy to suppose that it is only in a few exceptionally favoured districts that fruit can be profitably grown: the appearance of the trees and the abundant crop of strawberries at the Woburn Experimental Fruit Farm are sufficient to demonstrate that a field of ordinary arable land of average fertility, with nothing to recommend it for fruit-growing beyond having a gentle slope to the south-west, and with a reputation amongst farmers of being the most unmanageable in the district, may be rendered highly suited for the production of fruit. To produce such results, however, right methods of procedure are, of course, essential, and nothing could be more striking than the difference between the bulk of the apple-trees at the farm, and those growing on two plots where the planting and subsequent treatment were such as is usually adopted by farmers: the ground where these trees were had, indeed, been properly trenched and cleaned once, but the trees had been carelessly planted, the branches had not been cut back, and the weeds had been subsequently allowed to grow; the result was that along the branches there were only a few half-dead leaves of not more than one-fifth of the proper size, and it would have required a trained horticulturist to have recognised that these trees were of the same variety as those which had been properly tended.

Visitors were also much struck by the evidence which the results at the farm afforded of the hardiness of English fruit trees. No season could have been more trying for recently-planted trees than that just experienced. A very wet autumn, during which the heavy soil of the farm was unworkable, was followed by a winter of almost unprecedented severity, and this, in its turn, by a still more trying period of drought. Yet, with the exception of the young stocks and a few strawberry plants, the mortality amongst the thousands of trees and bushes brought on to the ground in the autumn, was confined to about six individuals and half of these were killed through the improper method purposely adopted in planting them.

All readers of NATURE will wish success to an enterprise so well begun and so liberally conducted, which is clearly destined to afford results of high economic and scientific value.

THE REVISION OF THE "BRITISH PHARMACOPŒIA."

THE last edition of the "British Pharmacopœia" was issued in 1885, and though a thin volume of "Additions" was published by the General Medical Council in 1890, the progress of science and the requirements of medical practice have rendered necessary a complete revision of the official handbook. The work has accordingly been entrusted to a Committee of the Council, consisting of Sir Richard Quain, F.R.S., Chairman, the only remaining member of the Committee of 1885; Sir Dyce Duckworth and Mr. Carter, of London; Dr. Leech, of Manchester; Dr. Batty Tuke, of Edinburgh; Dr. Donald MacAlister, of Cambridge; Dr. McVail, of Glasgow; and Dr. Atthill and Dr. Moore, of Dublin. Dr. Nestor Tirard, of King's College, London, has been appointed secretary to the Committee, and Prof. Attfield, F.R.S., of the Pharmaceutical Society of Great Britain, general editor. On questions of chemistry, Dr. T. E. Thorpe, F.R.S., Principal of the Government Laboratory at Somerset House, with Prof. Emerson Reynolds, F.R.S., of Dublin, and Prof. Tilden, F.R.S., of the Royal College of Science, have been invited to act as scientific referees. Mr. W. T. Thiselton-Dyer, F.R.S., Director of the Royal Botanic Gardens, Kew, and Mr. Holmes, Curator of the Pharmaceutical Society's Museum, have received a similar invitation as regards botanical questions. The rapid growth of experimental pharmacology has, moreover, rendered it desirable to enlist expert assistance in regard to the physiological properties and actions of new remedies, and accordingly difficult questions of this nature will be referred to Dr. Lauder Brunton, of London, Prof. Fraser, of Edinburgh, and Prof. W. G. Smith, of Dublin. Lastly, on matters of pharmacy, the Pharmaceutical Society have been asked to give their valuable aid, and have promptly formed a strong committee of practical experts. To this committee many questions as to the compounding and preparation of drugs will doubtless have to be referred.

A circular inviting suggestions for the improvement of the "Pharmacopœia" has been addressed to the several universities and medical licensing corporations of the United Kingdom, and from the majority of these careful and elaborate replies have been received. They contain numerous proposals for the omission of doubtful or obsolete preparations, for the incorporation of new drugs that have come into practical use since 1885, and for the simplification and correction of the text in general.

In response to requests transmitted through the Privy Council to the medical authorities of the colonies and India, a very large body of materials, submitted with the object of adapting the "Pharmacopœia" to the requirements of the empire at large, have reached the editing committee. These open up a multitude of somewhat difficult questions; for though the "Pharmacopœia" is by law recognised as the official standard of reference at home, it has not the same legal sanction outside the British Isles. While therefore it is possible that something may be done as regards the recognition of important natural drugs used in Indian or colonial practice, it is highly probable that these may have to be relegated to a special appendix. The desire to go as far as may legally be practicable in making the "Pharmacopœia" an im-

perial one is, however, highly laudable, and should be encouraged with a view to the unification of British medical science. It is further announced that a long-deferred step is about to be taken by the introduction of the metric system into the body of the work. In the present edition the centimetres and grammes of science appear modestly in the supplementary pages dealing with volumetric processes, and then only as an alternative to grains and "grain-measures." We understand that in the new revision centimetres and grammes will be made official in all the monographs of the text, side by side with the still legalised grains and ounces, minims and drachms. This change will bring the British handbook into line with the official dispensatories of all other civilised States, and should tend to hasten the time when the international system of metric weights and measures shall acquire full legal authority in this country.

It thus appears that the Medical Council's Committee have undertaken the task of revision with an adequate sense of their responsibility. They have in the suggestions of the medical authorities at home and abroad, and in the useful digests of the literature of pharmacy, prepared from year to year by their reporter, Prof. Attfield, ample materials whereon to base their deliberations. As a body of physicians representing the supreme council of the profession, they are eminently qualified to judge as to the requirements of practical medicine and clinical therapeutics. Where their domain borders on that of the specialist in chemistry, botany, pharmacy, or physiological pharmacology, they propose to have recourse to the most skilled representatives of these branches of science. The result of their labours, thus conceived and carried out, will be awaited with interest not only by practitioners of medicine and pharmacy, and by manufacturing chemists, but by all who have sympathy with the application of science to human needs.

THE FIRST MERIDIAN.

AT the recent Geographical Congress in London, the question of the first meridian was discussed with particular interest.

It was proposed that the first meridian should not be established officially, but should merely be settled with a view to producing an international map to the scale of millionths. M. A. de Lapparent has written an article in *La Nature* on the subject, of which the following is an analysis; it is a noteworthy occurrence that a Frenchman should have taken up the subject with such interest, for the French has hitherto been the only nation to reject the Greenwich meridian. In the preliminary discussions they have brought upon themselves many reproaches for hindering a scientific work the use of which every one had recognised, while they themselves had no principle to bring forward to support their objections. The matter has been much discussed amongst them, and at the Geographical Society of Paris, by a special commission, it was decided that the map should be accepted. It was considered best that France should not be the only country to refuse the project; nevertheless, it was decided to insist on the metric system being used, for here a principle was involved.

On this subject M. de Lapparent writes as follows:—

"Thus, true to its habit of fighting for its views, France has again showed itself champion of the metric system, offering to make, for the scientific and rational interest, a sacrifice of national self-love. It would be impossible for it to capitulate on the question of the system, for here a principle is concerned; but the choice of a meridian, depending on no logical consideration, could be more easily granted. Evidently the proposed map, if ever produced was to be arranged so as to be a help to already existing aps, the latter being in great majority on the meridian of Greenwich; by wishing to impose the meridian of Paris (which would not have been a success), it would have caused greater trouble than the contrary case. Henry IV. estimated that Paris was worth a mass; the French delegates, however, said on their side that the concession of a meridian, for a special and determined work, was quite worth the agreement which was expected to be established in view of the adoption, for the same purpose, of the metric system."

Many of our own countrymen have regretted that the public spirit prevented the system being used officially in Britain.

However, the acceptance of the Greenwich meridian well deserved a recompense, and the vote was unanimously carried that the metric system should be used for the map.

It is worth observing that the subject was discussed with remarkably few disagreements, considering that the congress was international. This seems to show that the time is fast approaching when national prejudices will be done away with if they support illogical theories; if principles are involved, it is right they should be adhered to, but they should not be allowed to hinder an enterprise profitable, perhaps, to all humanity.

NOTES.

THE *Times* of yesterday published a telegram, dated September 17, from Sandefiord, Norway, received through Reuter's Agency, stating that advices received at Sandefiord from the Danish trading station of Angmagsalik, on the east coast of Greenland, state that towards the end of July a three-masted ship, with a short foremast, was seen by Eskimos on two occasions firmly embedded in drift ice. On the first occasion the ship was observed off Sermiligak, 65° 45′ lat. N., 36° 15′ long. W.; and the second time off Sermelik. 65° 20′ lat. N., 38° long. W. It is believed tha the vessel was Dr. Nansen's *Fram*, and that she was on her return journey. In any case, however, no positive news of the exploring vessel is expected to arrive until next year.

ON Wednesday, Sept. 11, a Reuter telegram announced that the steam yacht *Windward*, which took out the Jackson-Harmsworth Polar Expedition, had arrived at Vardö, and on Thursday another telegram, through the same Company's agency, stated that the expedition, after leaving Archangel, passed the winter on Franz Joseph Land, from which place a start was made in the middle of July. The crew appear to have suffered severely from scurvy, and all the members of it are more or less weakened by the malady. Three of the men succumbed, and two others were removed to the hospital at Vardö.

THE *Standard* states that the excavations that are being carried out by the Greek Archæological Society on the site of ancient Eleusis, a few miles from Athens, have just yielded some results of exceptional importance. In a very ancient and well-preserved tomb, there have been found, in addition to the skeleton of a woman, a number of articles, including earrings of fine gold, silver, and bronze, several finger rings, sixty-eight small vases of various shapes in terra-cotta, two tripods, three Egyptian scarabæi, and a small statuette of the goddess Isis in porcelain. These discoveries leave no doubt of the fact that the celebrated mysteries of Eleusis were of Egyptian origin, and were borrowed from the religious rites of the ancient Egyptians. These important relics have been deposited in the National Museum.

A REUTER'S telegram of September 11, from Berne, reported the fall of a huge mass of ice from the Altels Glacier upon the hamlet of Spitalmatte, in the Upper Gemmi Pass, causing the death of at least ten persons, and the loss of, it is estimated, two hundred head of cattle. A stretch of land nearly two miles

in length has been overwhelmed, and the pass has been partially blocked.

THE death is recorded of Dr. L. Galassi, Professor of Medical Pathology in the University of Rome; Dr. Friedrich Miescher, sometime Professor of Physiological Chemistry, and Dr. von Sury, Professor of Forensic Medicine in the University of Basel.

DR. RUFFER is, we are sorry to learn, suffering from an attack of diphtheritic paralysis, and will not, in consequence, be able to deliver his intended course of lectures at the British Institute of Preventive Medicine, or, indeed, do any work for some time to come.

THE following lectures will be delivered at the Royal College of Physicians during the coming year:—The Goulstonian Course by Dr. Patrick Manson; the Lumleian Lectures by Sir Dyce Duckworth; the Croonian Lectures by Dr. George Oliver; and the Bradshaw Lecture by Dr. Bradbury. The Croonian lecturer for 1897 is Dr. Greenfield.

THE Berlin Academy of Sciences will award the Steiner prizes, of the respective value of 4000 and 2000 marks, for papers in continuation of J. Steiner's work on curved surfaces. The essays must be submitted to the Academy before the end of 1899.

AMONG a number of plumassier's bird-skins, said to have been brought from the foot of the Charles Louis mountains in New Guinea, has been found the skin of a most remarkable new Bird of Paradise of the genus *Astrapia*, conspicuous for its crimson gorget and black-and-white tail. This specimen, which has been secured for the Tring Museum, has just been described by Mr. Walter Rothschild as *Astrapia splendidissima*.

A NEW part of the quarto *Transactions* of the Zoological Society, which will be issued on October 1, will contain an important memoir on the Dinornithidæ, by Prof. T. Jeffery Parker. The author enters at length upon the osteology, classification and phylogeny of these extinct birds, giving special attention to their cranial characters. Prof. Parker is inclined to associate the Moas with the Kiwis (Apterygidæ), rather than with any other existing family of the class of birds.

WITH the new number that has just been issued, the publication of that valuable American periodical *Insect Life* comes to an end. The cessation takes place, we are told, for administrative reasons. Happily, the good work which it accomplished will be continued in two series of bulletins from the Division of Entomology of the U.S. Department of Agriculture. A new series of general bulletins will be begun, and will contain short reports on special observations, and the miscellaneous practical and economic results of the work of the division, and in directions of general interest. This first series will be sent to all the present readers of *Insect Life* who desire them. The second series of bulletins, published at rarer intervals, will publish the results of the purely scientific work of the members of the office force, and will consist largely of longer or shorter monographic papers on groups of North American insects. This series will be distributed only to libraries and to working entomologists. The publication of the divisional series of circulars of information upon especially injurious insects, of farmers' bulletins upon special entomological topics (principally methods of treatment), and of occasional special reports will be continued.

THE Third Report of the Royal Commission appointed to inquire what light-houses and light-vessels it is desirable to connect with the telegraphic system of the United Kingdom by electrical communication, stated that the value of the warning conveyed to passing vessels by the display of storm signals, on the occasion of the approach of heavy gales, could scarcely be overestimated, and recommended that the light-houses on the most prominent points of the coast of the United Kingdom, with which electrical communication exists, should be made storm-warning stations. In compliance with this recommendation the Meteorological Council have now made arrangements for the supply of storm-warning telegrams to twenty-five prominent headlands on the coast, for the benefit of passing vessels, in addition to the telegrams at present forwarded to ports and harbours, which are intended more particularly for the use of vessels leaving the places at which the signals are hoisted. The signals used are canvas cones, with point upwards or downwards, to signify whether northerly or easterly, or southerly or westerly gales are expected, and are practically the same as those originally adopted in 1860 by Admiral FitzRoy, then chief of the Meteorological Department of the Board of Trade. The light-house authorities have readily assisted in carrying out the recommendation of the Royal Commission, by allowing their light-keepers to undertake the management of the signals.

WE have received a volume of meteorological observations made at Rousdon Observatory during the year 1894, under the superintendence of Mr. Cuthbert E. Peek. This observatory is situated a short distance within the eastern boundary of Devonshire, in close proximity to the cliff, at an elevation of 516 feet above mean sea-level, and forms an important station of the Royal Meteorological Society. In addition to very complete meteorological observations, experiments of various kinds are carried on, in connection with evaporation, agriculture, &c. Mr. Peek remarks that, from an agricultural point of view, the year 1894 may be briefly summarised as a year of plenty, but with prices too low to pay for the cost of production. Since 1883, a daily comparison of the weather experienced at this observatory with that predicted for the district in the forecasts issued by the Meteorological Office has been made. The published daily weather reports were received the day following the date of issue, and the forecasts contained in them were therefore not seen until after the actual weather experienced had been recorded. The results have proved of much interest; for the year 1894, ninety-three per cent of the forecasts for wind and for weather, separately compared, were found to be trustworthy. A table of comparisons for the years 1884–94 shows that the percentage of successful forecasts has improved year by year.

THE preparation of artificial human milk has from time to time occupied the attention of investigators, but so far, according to Dr. Backhaus, no satisfactory substitute has been produced in the place of human milk. Dr. Backhaus has, however, quite recently endeavoured to supply this deficiency, and stimulated by Kehrer's method he has succeeded in producing so-called artificial human milk. The milk is carefully collected with the usual hygienic precautions of cleanliness, &c., and then submitted to fermentation by means of rennet, in the course of which a relatively rich milk serum is procured containing albumen and milk sugar. This serum is carefully sterilised, and by the addition of cream a material is produced which closely resembles human milk, which may be varied in composition according to the age or particular requirements of the individual. Since, however, our knowledge of the properties possessed by the natural fluids of the body has been recently extended in so remarkable a manner, the subject of artificial milks has become invested with new considerations, which a few years ago were not even suspected. In the course of his paper Dr. Backhaus points out that the sterilisation of milk should, if possible, be carried out on the large scale in dairies before distribution, that in this way better apparatus being to hand, more cleanly besides more effectual results will be obtained than when it is left in the hands of private individuals. As demonstrating the importance of freeing the milk from impurities before use, Dr. Backhaus mentions that

the city of Berlin alone consumes daily with its milk 300 cwt. of cow dung!

ALTHOUGH the extension of geological research into distant parts of the earth has shown that the divisions of time originally made in Europe are not always applicable to other areas, yet it is possible that the greatest geological division-lines that are recognised may represent world-wide periods of rapid change. Such is the view expressed by Prof. Le Conte in a paper on "Critical Periods in the History of the Earth," published by the University of California. He considers that in the evolution of the earth there must have been now and again, amid many smaller local changes, readjustments of the crust affecting the whole earth, with something approaching simultaneity. Such universal changes must be used to mark out the primary divisions of time: they are marked by widespread unconformities and the birth of great mountain-ranges, and as consequences of these changes in physical geology there follow remingling of faunas, the extinction of many types, the more rapid evolution of new forms, and the origin of new dominant classes. We thus have an alternation of short "critical" periods of extensive change and long periods of gradual change, the former marking the commencement of the great time-divisions of the earth's history. Four such critical periods can, in Prof. Le Conte's opinion, be recognised—the pre-Cambrian, the post-Palæozoic, the post-Cretaceous, and the Glacial. Comparing these with one another, he finds progressive change in their character; each one is shorter in duration than the previous one, and involves greater climatic changes and increased faunal effects from the introduction of new dominant types.

DR. GERHARD SCHOTT has published some interesting maps concerning the present conditions of sail navigation, which are appended to his paper on the subject appearing in the *Zeitschrift der Gesellschaft für Erdkunde*. They are chiefly compiled from log-books examined at the Deutsche Seewarte, Hamburg. The two main lines of voyages for German sailors are the "saltpetre trips" to the west coast of South America, and the "rice trips" to India and the Straits Settlements. A map divided into zones of equal travelling times from the Lizard shows the remarkable fact that the mouth of the Congo is one of the most difficult parts to reach in a sailing vessel. The Cape and Patagonia can be reached in the same time. The southern Indian Ocean forms a kind of racecourse along which the vessels speed to Australia in the same time as it would take to reach Zanzibar. Adelaide can be reached in ninety days, and so can Chile. New York, which requires forty days, is in that respect as distant as Panama, and is one of the most inaccessible ports for a sailing vessel, especially in the winter. The return is easier, and can be accomplished in twenty-five days, whereas the return from Panama takes sixty. The return from Australia is equally lengthy round the Cape as by Cape Horn, and the latter route is now preferred owing to the notoriously dangerous character of Cape Agulhas. Needless to say, the Suez Canal is quite useless for sailing vessels. Even apart from the fact that the Red Sea is most difficult to navigate, the canal dues exclude vessels whose vitality lies solely in the cheap freights they can offer in competition with steamers. With the modern construction of sailing vessels, which are built almost exclusively of iron and steel, the only enemies seriously feared are fogs, icebergs, and dead calms, to which we must add, in the much-frequented ocean highways of the northern Atlantic, the fast mail steamer. The average skipper does not mind a storm, but rather welcomes it, as it makes him go all the faster.

THE *Journal of the Franklin Institute* states that the recent trials of electric locomotives at Nantasket Beach, near Boston, and at Baltimore, have so satisfactorily demonstrated the superiority of this class of motor over the steam locomotive for short hauls, that it is now very generally admitted that the near future will witness a very extensive application of the new form of motive power for short branch lines, tunnel haulage, &c. At the Nantasket Beach trials, it is stated that a speed exceeding sixty miles an hour was attained, and at Baltimore the test of the electric locomotive designed to draw trains through the tunnel, 7430 feet long, in that city, was highly successful. A maximum speed of fifty miles an hour is to be developed, and it is guaranteed that the locomotive will pull 1200 tons at a speed of thirty miles an hour. The system has been in practical and regular operation on the Nantasket Beach Railway since the end of June last.

ACCORDING to the *Engineer*, a French physicist, M. Denayrouze claims to have discovered a means of increasing the illuminating power of gas about fifteen times. In his lamp M. Denayrouze employs a spherical-shaped metallic body, and a mantle capable of being raised to incandescence. In the body of the lamp is fixed a tiny motor, which works a ventilator, and which receives current from a couple of small accumulators. The electrical energy required is said to be only $\frac{1}{3}$ volt and $\frac{1}{15}$ of an ampere, and to be sufficient to force a current of air through the mantle and to cause the gas to burn with remarkable brilliancy. The burner is said to consume seven litres of gas per carcel, and lamps have been made having an illuminating power of 800-candle power.

SPEAKING of some experiments in marching, which have recently been carried out at the request of the German War Office, by some students of medicine of the Friedrich Wilhelm Institute in Berlin, who for the purpose wore the regulation uniforms and carried the full field service equipments, the *British Medical Journal* says:—"The marches performed varied from 22 to 33 miles, and were executed in all kinds of weather. The weights or loads carried varied from 48 to 68 lbs., the full service equipment of the German infantry soldier averaging 70 lbs. That of our own infantry does not usually exceed 60 lbs. The conclusions arrived at by the medical officers in charge of the experimental observations were practically as follows: When the load is not excessive and does not exceed 48 lbs. a march of twenty-five miles executed in cool weather (60° F.) is readily performed, and has no deleterious effects upon the man, even if continued for some days consecutively. With a mean temperature of 70° F. a similar load carried the same distance has a considerable temporary effect upon the organism, necessitating a rest of at least ten hours in the twenty-four. A load of 68 lbs. could not be carried twenty-five miles without inducing grave physiological disturbance, necessitating a full day's rest on the following day. This weight was not readily carried day by day without derangement of health over greater distance than fifteen miles. A weight of 60 lbs. was the maximum weight which could be carried on consecutive days for twenty-five miles by a man weighing 11 stone during ordinary summer weather consistently with health. It is not stated whether the men by whom these experiments were made were picked individuals, or what was their dietary."

THE current number of *The Leisure Hour* contains an interesting article by E. Whymper, on some high mountain observatories, accompanied by illustrations and short accounts of the difficulties experienced and the results attained. The observatories described are:—Mount Washington, in New Hampshire, U.S.A., 6286 feet high; it was established in 1870, but is now closed. Pike's Peak, in Colorado, 14,134 feet high, was erected in 1873, and closed in 1888. This station was celebrated for its electrical storms. The most elevated station is on the top of the Misti, near Arequipa, in Peru. This is 19,200 feet above the sea, but notwithstanding its great elevation, the ascent is comparatively easy. About twelve miles to the north

there is a mountain called Charchani, about 20,000 feet high; an observatory was established just below the snow-line, at the height of 16,650 feet, in the years 1892–3, but is now abandoned. The article contains a graphic account of the difficulties of establishing two observatories on Mont Blanc, one at 14,320 feet, and the other on the summit, at 15,780 feet, by M. Vallot and M. Janssen, respectively. The meteorograph for the summit of Mont Blanc has been constructed by M. Richard at a cost of £750, and the clockwork is calculated to remain in action for eight months.

USEFUL and practical publications continue to issue from the various botanical experiment stations in the United States. We have on our table the following:—From Kansas State Agricultural College, *Bulletin* No. 50, comprising a list of Kansas weeds, with descriptions, and figures of the seedling forms; from Cornell University, an essay, by Mr. G. F. Atkinson, on "Damping Off," containing a description, with figures, of the various parasitic fungi which accompany this phenomenon, including a new species, *Volutella leucotricha*; and "Studies in Artificial Cultures of Entomogenous Fungi," by Mr. R. H. Pettit, also illustrated by plates.

THE Report of the Botanical Exchange Club of the British Isles for the current year is issued, with a list of Desiderata. The main portion of the very useful work done by this Association rests with two or three individuals. This work would be greatly promoted by the addition of a few new subscribers, who should address themselves to Mr. Charles Bailey, College Road, Whalley Range, Manchester.

THE following colonial botanical publications have reached us:—The *Bulletin* of miscellaneous information of the Royal Botanic Gardens, Trinidad, for July, containing a number of notes on native and cultivated plants in the colony, by Mr. J. H. Hart; *Botany Bulletin*, No. 10, of the Department of Agriculture, Brisbane, consisting of contributions to the Queensland flora, by Mr. F. M. Bailey; *Proceedings* of the Royal Society of Queensland, vol. xi. pt. 1, with the annual address of the President, Mr. R. L. Jack, on "The Higher Utilitarianism."

MESSRS. G. PHILIP AND SON have reprinted for Dr. Mill the paper on "The English Lakes," which, under the title of "On the Bathymetrical Survey of the English Lakes," the author contributed to the July and August numbers of the *Geographical Journal*. The book is nicely got up, and is illustrated by numerous photographic views, maps, and diagrams.

A NEW edition—the third—of Clowes and Coleman's "Quantitative Chemical Analysis" has been sent to us by Messrs. J. and A. Churchill. The work has undergone certain changes since the publication of the second edition, the matter having been increased, the text revised, and some new figures added.

THE September part of *Science Progress* contains the following articles:—"Progress in the Study of the Ancient Sediments," by J. E. Marr; "On the Respiratory Function of Stomata," by F. Frost Blackman; "The Zoological Position of the Trilobites," by H. M. Bernard; "Some Metasomatic Changes in Limestones," by A. Harker; and "The Decomposition Products of Proteids," by Dr. T. Gregor Brodie.

THE series of small books, entitled "Encyclopédie Scientifique des Aide Mémoire," which is being brought out conjointly by Messrs. Gauthier-Villars and G. Masson, of Paris, has had another addition made to it by the publication of "Cubature des Terrasses et Mouvement des Terres," by G. Dariès.

THE paper "On the Cost of Warships," which was read by Dr. F. Elgar at this year's summer meeting of the Institution of Naval Architects, has been issued in pamphlet form by the Institution. The pamphlet also contains a report of the discussion on the paper which took place at the meeting.

WE have received the *Memoirs and Proceedings of the Manchester Literary and Philosophical Society*, fourth series, vol. ix., No. 3, 4, and 5, and the *Journal of the Asiatic Society of Bengal*, vol. lxiv., part 2, No. 2.

MR. R. W. PAUL, of Hatton Garden, has sent to us advance sheets of his new catalogue of electrical testing and measuring instruments. Many of the instruments are figured.

THE University Correspondence College has issued its Intermediate Arts Guide, No. x., with the papers set at London University, July 1895, and articles on the special subjects for 1896, and its London Inter. Science and Prel. Sci. Guide No. vii., with the papers set at London University, July 1895.

THE August numbers of the *Journal of the Royal Microscopical Society* and of *Clinical Sketches* have reached us; also part vi. of the *Katalog der Bibliothek der Kaiserlichen Leopoldinisch-Carolinischen Deutschen Akademie der Naturforscher*, Halle; and Messrs. Friedländer and Söhn, Berlin, have sent us No. x. to xiv. of *Naturæ Novitates*.

THE additions to the Zoological Society's Gardens during the past week include a Rhesus Monkey (*Macacus rhesus*, ♂) from India, presented by Miss E. S. Cooper; a Smith's Dwarf Lemur (*Microcebus smithi*) from Madagascar, presented by Miss Ruby Woolcott; a Yellow-fronted Amazon (*Chrysotis ochrocephala*) from Guiana, presented by Mr. W. Page; a Beautiful Grass Finch (*Pæphila mirabilis*, ♂) from Australia, presented by Mr. Gerard O'Shea; a Brazilian Tortoise (*Testudo tabulata*) from Brazil, deposited; three Boas (*Boa constrictor*) from Brazil, purchased; a Wapiti Deer (*Cervus canadensis*, ♂), two Triangular-spotted Pigeons (*Columba guinea*), a Spotted Pigeon (*Columba maculosa*), two Crested Pigeons (*Ocyphaps lophotes*), two Half-collared Doves (*Turtur semitorquatus*), two Vinaceous Doves (*Turtur vinaceus*), bred in the Gardens.

OUR ASTRONOMICAL COLUMN.

THE SPECTRUM OF MARS.—In connection with the recent discussion as to the presence or absence of the bands of water vapour in the spectrum of Mars, Dr. Janssen has published further particulars of the observations made by him in 1867 (*Comptes rendus*, July 29). He points out that even with the quantity of vapour in our own atmosphere, the bands would be all but invisible to an observer on Mars if the solar light were reflected normally from the earth's surface, and since the general conditions of the planet point to its atmosphere being less important than our own, it is easy to understand that the detection of the bands is a very delicate observation. To reduce the absorptive effect of the terrestrial atmosphere, observations should be made at a high altitude, and the use of the lunar spectrum as a term of comparison is also important. As to the apparatus required, Dr. Janssen does not consider large telescopes indispensable, as even with them the telluric bands can only be observed in their totality. Previous to observing the spectrum of Mars, Dr. Janssen had been engaged in an extensive study of the spectrum of water vapour as exhibited by a tube 37 metres in length. The observations of Mars were made on May 12-15, 1867, from a station on Mount Etna at an altitude of nearly 3000 metres; at meridian passage the altitude of the planet was 72°, and at sunset, when the observations were commenced, it was still more than 60° above the horizon, while the moon was a little lower. The cold was excessive during the nights of observation, and the quantity of vapour contained in the atmosphere overlying the place of observation would not be able to give indications of the telluric groups near C and D, according to the experiments with the long tube. Under these highly favourable conditions, Dr. Janssen found feeble but certain indications of the groups at C and D, and he is confident that future researches will justify the conclusion at which he arrived.

APPARATUS TO ILLUSTRATE DOPPLER'S PRINCIPLE.—The movement of the lines in a spectrum due to the approach or recession of the source of light is now so thoroughly well known, and has become of such importance in astronomical questions, that a laboratory experiment to illustrate this fact will be of interest. The idea, which we owe to the Russian astronomer, A. Belopolsky, and which was published in the *Memorie della Società Degli Spettroscopisti Italiani*, is as follows:—We know that the wave length of light ray can be varied by reflecting the light into a movable reflector, the amount of variation depending on the velocity of the reflector and the angles of incidence and reflection. By allowing the light to fall as vertical as possible on to the reflector, the variation of the wave-length can be magnified at will by increasing the number of reflectors. Now the apparatus suggested consists of two cylinders with parallel axes capable of being rotated very rapidly in opposite directions. On the surfaces of each a large number of reflectors are fixed, which are so arranged that when a ray of light from a heliostat falls on the reflector of the first cylinder, then from this on to a reflector on the second cylinder, and so on backwards and forwards, and finally into the slit of a spectroscope.

By closing first half the slit and photographing the spectrum, and then, on the same plate, photographing again the spectrum, only this time using the other half of the slit, the movement of the lines will thereby be doubly recorded on the plate, the double displacement being due to the two directions of rotation of the cylinders during the first and second exposure respectively.

Whether this idea can be carried out practically is yet to be seen, for there are many difficulties connected with it, such as the great velocities of the cylinders, perfect rigidity, &c., which will be hard to overcome.

THE PRÆSEPE CLUSTER.[1]

THIS work belongs to a class of investigations whose number has been steadily increasing in the last few years. The discussion of the relative motion of stars in loosely aggregated groups is a study that may throw light on intricate questions connected with the structure of the cosmos; and in this point of view, the Pleiades group has been discussed by several astronomers since Bessel laid the foundation for such inquiries more than fifty years since. The cluster in Perseus, the stars about the nebula of Orion and some other groups have already engaged the attention of astronomers, but nothing more complete or more interesting has appeared than the present investigation due to Dr. Schur; and it will hold its own till lapse of time gives a more trustworthy hold upon the small mutual displacements which successive investigations may reveal, for greater accuracy of measurement can scarcely be expected.

The present work divides itself naturally into three sections. In the first is given the results of a thorough examination of the instrument and of the constants of reduction, together with the triangulation of the group undertaken by Dr. Schur. In the second part is presented the measurements of position angle and distance of the stars by Dr. Winnecke, made with the Bonn heliometer in 1857 and 1858; and in the third, the comparison of the results of the measurements made with the Bonn and Göttingen heliometers respectively.

The investigation of the errors that accompany heliometrical measurement and their elimination, however complete and satisfactory, will only be of interest to experts in the use of this delicate instrument; but as evidence of the accuracy finally attained, we may quote the resulting values of the scale, derived from the measurement of the distances between stars in different parts of the heavens, whose places were determined with great accuracy for the reduction of the heliometer observations made in the Transit of Venus expedition. The places of the "Victoria" stars have been taken from Dr. Gill's paper:—

	Dr. Schur's value.	Dr. Ambronn's value.
	"	"
Stars in Cygnus	40·01601	40·01915
,, Hydra	40·01506	40·01610
,, near Pole	40·01562	40·01678
"Victoria" stars	40·01750	40·01710

In a measurement of approximately 2°, the two observers would assign values different by only 0"·22, a degree of accuracy upon which they may be congratulated.

Notwithstanding this apparent accuracy, there still remains an unexplained discrepancy between measures made with the heliometer and the distances deduced from meridian observations. Dr. Gill has called attention to this peculiarity, and has suggested an explanation which does not seem to be satisfactory to Dr. Schur, or to apply to the Göttingen instrument, where a distance of about 1000" appears to be measured too small by approximately a quarter of a second. This difference disappears for distances of about 5000", and reappears with an opposite sign for the greatest distances possible to measure with the Göttingen heliometer. Dr. Schur employs, and justifies the employment of an empirical correction of the form—

$$\text{Correction} = as + bs^2 + cs^3$$

where the unit of s is 1000 seconds. On the assumption that the correction disappears for $s = 5$, and is at a maximum for $s = 1·3$, he derives the following values for the coefficients:—

$$\text{Correction} = 0''·473\,(s - 0·50s^2 + 0·06s^3).$$

The investigation of the corrections to the readings of the position circle is made with quite as much care as that devoted to measures of distance, but the probable error of a distance measure is only half as great as that of a measure of angle. This result, confirmed as it is by similar discussions in the case of other heliometers, induces Dr. Schur to base his triangulation of the group on measures of distances, reserving the measures of position angle for the orientation of the entire group after the solution of the triangles. The observations began in February 1889, and are continued till March 1892, and embrace forty-five stars of the group. The combined measures give rise to 123 measured distances, and each of these is compared with the distance computed from Asaph Hall's catalogue of the stars of the Præsepe Group ("Washington Observations," 1869, Ap. iv.), giving rise to as many equations of condition. These are collected into an enormous normal equation of seventy-four unknowns. The solution of such an equation is sufficient to make the boldest arithmetician waver, and seek some approximate solution, but Dr. Schur preferred to adhere strictly to the method of elimination proposed by Gauss, and after weeks of labour brought his work to a successful conclusion. Such a labour so carried out in the University of Göttingen, is a not unfitting tribute to the memory of the great mathematician whose name is connected with that particular form of solution. With a similar disregard to the quantity of labour involved, and with all the accuracy attainable, Dr. Schur finally fixes the coordinates of the forty-five stars under consideration.

A melancholy interest is attached to the second part of the memoir in which the results of Winnecke's measures are given to the world. The introduction is the work of that distinguished astronomer, and it will be a matter of sincere regret to all that his state of health has not permitted him to continue to the end an investigation of so much value and thoroughness. That the task of completion and editing has fallen to Dr. Schur is fitting and appropriate, and must have been to him a labour of love. The principal difference in the methods of observation at Bonn (where Winnecke's observations were made) and Göttingen consists in the greater reliance placed by Winnecke on the measures of position angle, a confidence scarcely warranted by the probable error deduced from the observations, which Dr. Schur gives as follows:—

Probable error in distance of 2000" ...	= ± 0"·218
,, ,, in position angle (in a great circle)	= ± 0"·379

The final result is to give a catalogue of the places of 45 stars for the epoch 1858, which are comparable with the catalogue of Dr. Schur for the epoch 1890·54. The comparison of these two catalogues and the discussion of the proper motion forms the third section of the work.

Dr. Schur first examines the relative accuracy of the two catalogues, and decides in favour of the more modern, in the proportion shown by the following:—

	Göttingen.	Bonn.
Probable error of distance (4000")	± 0"·193 ...	± 0"·354
,, ,, position angle	± 0"·359 ...	± 0"·506

From considerations based on these and similar facts drawn from meridian observations, Dr. Schur concludes that a difference of 0"·27 in the place assigned to a star in the two catalogues can hardly be regarded as a proof of the existence of proper motion. The difference between the coordinates both in R.A. and Declination, though larger than this quantity, is everywhere small and negative. The proper motion of ten of the stars has also been

[1] "Astronomische Mittheilungen von der Königlichen Sternwarte zu Göttingen." Die Oerter der helleren Sterne der Præsepe. Von Dr. Wilhelm Schur. (Göttingen, 1895.)

determined by Dr. Auwers from the meridian observations of Bradley and Mayer, and these show in the mean a correction to the heliometrically deduced proper motions of $-0^s{\cdot}0003$ and $+0''{\cdot}039$ in R.A. and Declination, respectively. This discrepancy is subsequently traced to corrections due to the fundamental catalogues employed, and the final star places given on pp. 298–9 possess an accuracy that will make them of value for many purposes.

Finally, a comparison is instituted between the proper motion of the group as observed, and the motion that might be expected from the progressive motion of the solar system. The result is not in very satisfactory agreement. The parallactic displacement of the solar system is

	$\Delta\alpha = -0^s{\cdot}0016$	...	$\Delta\delta$ $-0''{\cdot}020$
Proper motion, Auwers	$= -0^s{\cdot}0044$	...	$+0''{\cdot}007$
,, ,, other sources	$= -0^s{\cdot}0041$	...	$-0''{\cdot}032$

The question of absolute parallax enters here, and to this point Dr. Schur promises to return, possibly in connection with photographic researches. W. E. P.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

THE following appointments have recently been made abroad:—Bâle, Dr. R. Metzner, of Freiburg, to the Chair of Physiology; Barcelona, Dr. Gil Saltor Lavali to the Chair of Surgical Pathology; Breslau, Dr. Jacobi, Professor of Forensic Medicine; Bonn, Dr. Finkler, Ordinary Professor of Hygiene; Columbian University, Wisconsin, Dr. W. Reed to the Chair of Bacteriology and Pathology, and Dr. M. T. Phillips to that of Hygiene; Granada, Dr Rafael Mollá y Rodriguez, of Havana, Professor of Clinical Surgery; Genoa, Dr. Canalis, Ordinary Professor of Hygiene; Harvard, Dr. H. C. Ernst, Professor of Bacteriology; New York (Polyclinic) Dr. Wilbur B. Marple Professor of Ophthalmology, Dr. W. R. Pryor Professor of Gynœcology, and Dr. W. R. Townsend, Professor of Orthopædic Surgery; Prague (Bohemian University), Dr. J. V. Rohon Extraordinary Professor of Histology; Tomsk, Dr. F. Krüger Extraordinary Professor of Medical Chemistry; Würzburg, Dr. K. Rieger Ordinary Professor of Psychiatry; Zürich, Dr. H. von Wyss Extraordinary Professor of Forensic Medicine.

DR. J. H. HYSLOP has been appointed Professor of Logic and Ethics in Columbia College, New York. Dr. J. Allen Gilbert, of Yale, goes to the University of Iowa as Assistant Professor of Psychology.

ACCORDING to *Science*, Dr. Wilhelm Roux, of Innsbruck, has been called to the chair of Anatomy in the University of Halle; Dr. K. Seubert, of Tübingen, to the chair of Chemistry in the Technical High School, Hanover, and Dr. Kallius, of Göttingen, to the chair of Anatomy at Tübingen.

MESSRS. E. B. TITCHENER AND J. E. CREIGHTON have been made full professors in the Sage School of Philosophy in Cornell University.

PROF. MARK W. HARRINGTON has accepted the presidency of the University of Washington.

THE Aberdeen Town Council have agreed to give an annual contribution of £200 for the establishment of a department for instruction in agriculture, in connection with the University of Aberdeen, provided that a similar sum be given by the County Council.

THE prospectus of the Science, Art and Technical Schools, Plymouth, for the fourth session, 1895 96, has been issued. Copies may be had of the Secretary.

WE have received a copy of the syllabus of lectures to be delivered in the Engineering Department of the City of London College, Moorfields, during the coming session.

SOCIETIES AND ACADEMIES.

PARIS.

Academy of Sciences, September 9.—M. Marey in the chair.—A memoir was presented by M. Wladimir de Nicolaiew, entitled "On the attempt to show currents of electric displacement and on the magnetic induction of iron in the alternative state."—Results of solar observations, made at the Royal Observatory of the Roman College, during the first quarter of 1895, by M. P. Tacchini. The diminution of frequency of spots was maintained during this quarter with a secondary minimum in January. Protuberances showed the same minimum although the season was unfavourable for their observation.—On the forces developed by differences of temperature between the two main plates of a beam with continuous trusses, by M. H. Deslandres. From the experiments made, differences of temperature between the upper and lower plates of a continuous girder cause supplementary forces of compression and extension, frequently reaching in the hot season 2 kg. per millimetre.—Observations on M. Deslandres' note, by M. Maurice Lévy. An exact demonstration giving the means of deducing the strains in every case.—On a theorem in geometry, by M. Mendeléef.—On nitro-substitutions, by MM. C. Matignon and Deligny. The conclusions are given: (1) Isomerides of position have always been found to have the same heats of combustion within the errors of experiment; one only need be examined from a number of isomerides. (2) The mean difference in heats of combustion of a compound and its nitro-derivative is 45 Cal. Hence is deduced the equation

$$RCH + NO_3H \text{ liq.} = RCNO_2 + H_2O \text{ liq.} + 36{\cdot}7 \text{ Cal.}$$

that is, the exact value found by Berthelot for the formation of nitro-hydrocarbons.—On the explosion of endothermic gases, by M. L. Maquenne. The conditions of propagation of an explosive wave initiated by detonators are given, and the influence of this explosive character on the industrial applications of acetylene is pointed out.—Influence of the winter 1894–95 on the marine fauna, by M. Pierre Fauvel.—On a gigantic terrestrial tortoise, from a specimen living in Egmont Islands, by M. Th. Sauzier. Dimensions are given of a specimen of *Testudo Daudinii*, and compared with the dimensions of other known tortoises and the fossil *T. Perpiniana*.—Results of palæontological excavations in the Upper Miocene of the "colline de Montredon," by M. Ch. Deperet.—On a superior limit to the mean area affected by an earthquake, by M. F. de Montessus de Ballore. From Japanese observations it is deduced that this higher limit is 1200 square kilometres.

BOOKS, PAMPHLET, and SERIALS RECEIVED.

BOOKS.—Mental Physiology: Dr. T. B. Hyslop (Churchill).—A Text-Book on Applied Mechanics; Prof. A. Jamieson, Vol. 1 (Griffin).—Justus von Liebig: W. A. Shenstone (Cassell).—The English Lakes: Dr. H. R. Mill (Philip).—Light: H. P. Highton (Rivington).—Facts about Processes, Pigments, and Vehicles: A. P Laurie (Macmillan).—Ostwald's Klassiker der Exakten Wissenschaften, No 63 to 66 (Leipzig, Engelmann).—Müller-Pouillet's Lehrbuch der Physik und Meteorologie, new edition, by Drs. Pfaundler and Lummer (Braunschweig, Vieweg).—British Museum (Natural History) Mineral Department: An Introduction to the Study of Rocks (London).

PAMPHLET.—The Cost of Warships: Dr. F. Elgar (Institution of Naval Architects).

SERIALS.—American Naturalist, September (Philadelphia).—Psychological Review, September (Macmillan).—Strand Magazine, September (Newnes).—Picture Magazine, September (Newnes).

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